EXPERT REPORT IN SUPPORT
OF HONEYWELL DEFENSE
REGARDING THE TPE331-10R-511C
TURBOPROP ENGINE, SERIAL NUMBER P42145C,
INSTALLED ON DE HAVILLAND
DHC-3 OTTER
REGISTRATION N93PC
INVOLVED IN CRASH
NEAR SOLDOTNA, AK ON JULY 7, 2013

HONEYWELL AEROSPACE
PHOENIX, ARIZONA
SEPTEMBER 29, 2017

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BIOGRAPHY

I am responsible for providing aircraft accident investigation support for Honeywell Aerospace to the NTSB, FAA and other regulatory agencies around the world when accidents and incidents occur involving Honeywell engines or products. I also provide product safety oversight to the Honeywell Customer Satisfaction Board (CSB) process for assigned Aerospace products and technical expert support to the Law Department.

I have been in the Product Integrity organization since 2005 and joined AlliedSignal, now Honeywell, in 1997. Past positions held include: Six Sigma Plus Black Belt and Manufacturing Engineer for propulsion engines. I began my career in the propulsion development test organization.

I hold a Bachelor of Science degree in Aeronautical Technology from Purdue University and a Master of Science in Technical Management from Embry-Riddle University. In addition to a six sigma black belt certification, I hold an instrument rated private pilot's license, an airframe and powerplant license, a remote pilot airman certificate with a small UAS rating, and an Aviation Safety and Security Certification from the University of Southern California. I am also a full member of the International Society of Air Safety Investigators.

EXPERIENCE

During the previous 12 years, I have participated in about 200 investigations in support of Honeywell's product portfolio. My primary technical expertise is in the area of propulsion engines and encompasses broad areas of focus including: accident/incident investigation, failure analyses, engine operation and functional test, component manufacturing, sub-assembly and engine assembly, quality control, manufacturing and assembly records, statistical-based process improvements, acoustics, and vibrational analyses for all Honeywell propulsion and APU engines.

The Honeywell propulsion product suites include the T53, T55, LTS101, HTS900, TSE331 and the AGT1500 turboshaft series engines, the TPE331, LTP101, T53 turbo-propeller series engines, and the TFE731, ATF3, F124/F125, TFE1042, AS900, LF507/ALF502 turbofan series engines.

ACCIDENT SUMMARY

As summarized by the NTSB, "On July 7, 2013, about 1120 Alaska daylight time, a DeHavilland DHC-3T "Otter" airplane, N93PC, was destroyed after a collision with terrain shortly after takeoff from the Soldotna Airport, Soldotna, Alaska. The airplane was registered to Rediske Family Limited Partnership, Nikiski, Alaska, and was operated by Rediske Air, Inc. under the provisions of 14 CFR Part 135, as an on-demand charter flight. The commercial pilot and nine passengers were fatally injured. Visual meteorological conditions prevailed and no flight plan was filed for the flight destined to Bear Mountain Lodge, approximately 90 miles southwest of Soldotna".[1]

NARRATIVE AND SUPPORT OF NTSB INVESTIGATION

I was notified of the accident by the local Alaskan Honeywell field service engineer. After coordinating with Honeywell Product Integrity management, it was decided that the field service engineer, Mr. Mickey Selhay, would support the NTSB's on-scene investigation. During the course of this support, Mr. Selhay informed my management and me about the factual data obtained during the on-scene investigation.

The NTSB asked Honeywell to do an additional engine exam at our Product Integrity (PI) facility located in Phoenix, AZ. The engine, serial number P42145C was shipped to Honeywell in PHX and received on or about July 17, 2013. Due to scheduling conflicts as well as the government shutdown and worker furlough, the engine examination occurred on January 14-16, 2014 under the oversight of the NTSB Powerplant Chairman, Mr. Harald Reichel. On January 15, 2014 the propeller was examined under NTSB oversight at Ottosen Propeller & Accessories Inc. on 105 S 28th St, Phoenix, AZ 85034, a local Hartzell service center. The teardown of the engine disclosed that the engine was rotating and operating at the time of impact with terrain. The teardown examination of the propeller disclosed damage consistent with rotation and power at the time of impact with terrain. After the engine teardown was finished, the engine was loosely reassembled to protect the hardware during transport and storage once it had been released and returned in accordance with the NTSB instructions. On April 17, 2014, the propeller was picked up from Ottosen propeller and placed in the engine shipping

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[1] NTSB Video Study

container. At the time, the NTSB provided oversight of the opening of the engine container, the placement of the propeller components and the resealing of the engine container. The container was then shipped to Wasilla, Alaska, attn.: Kevin Wyckoff, on the same day.

During the accident investigation, Honeywell provided technical assistance to the NTSB. Honeywell did not produce or provide an engine examination report. Instead, Honeywell provided technical support and information to the NTSB Powerplant Chairman to be used to author the Powerplant Group Chairman's Factual Report.

ENGINE OVERVIEW

The TPE331 engine is a lightweight fixed-shaft engine designed to provide primary power for fixed wing aircraft (Figure 1). Like other turbine engines, it has four basic stages: intake, compression, combustion and turbine exhaust. The engine configuration can either be an inlet up or inlet down, but both contain the same basic components. The two stages of compressors and three stages of turbines are mounted on a common shaft and make up the power section of the engine. Approximately two-thirds of the energy from the fuel/air combustion is used by the turbine section to drive the compressor section. The remaining one-third of energy is used to drive the reduction gearbox, which in turn drives the propeller.

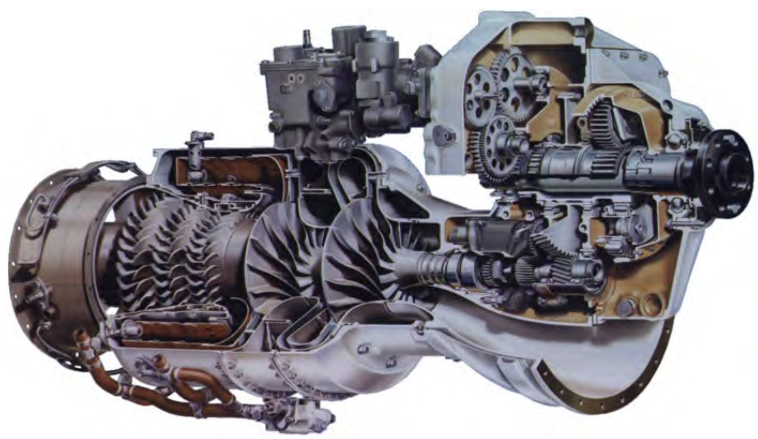

Figure 1. TPE331 Cut Away Illustration

At 100% speed, the power section (Figure 2) rotates at 41,730 RPM. The high speed/low torque output of the power section is converted by the reduction gearbox section (Figure 3) to low speed/high torque. Figure 2 and Figure 3 show an inlet up configuration as opposed to the inlet down configuration of the accident engine. At 100% speed, the reduction gearbox output to the propeller is 1,591 RPM (counter-clockwise rotating propeller, aft looking forward).

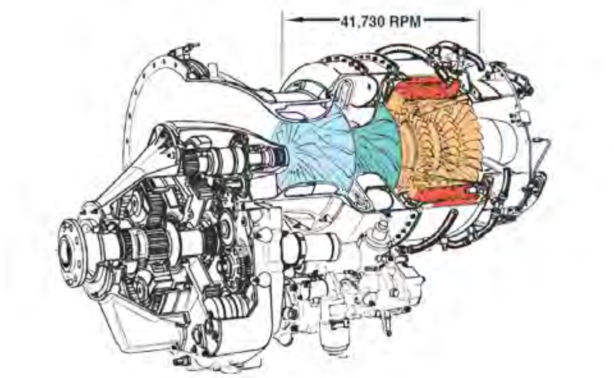

Figure 2. Power Section

The torsion shaft, which is positioned concentrically inside the main shaft, extends through the length of the main shaft. The torsion shaft is driven by a spline at the rear of the main shaft, and it drives the matched bearing and shaft set (high speed pinion) through a spline coupling at the front of the torsion shaft. The torsion shaft is designed to twist slightly with the application of power. According to the TPE331 Line Maintenance Training Manual[2], "the normal torsion shaft deflection can be as much as 11°, from minimum to maximum allowable engine power". The TPE331-10R-511C torsion shaft deflection along its axial length is approximately 8 degrees maximum, from the aft splines to the forward splines.

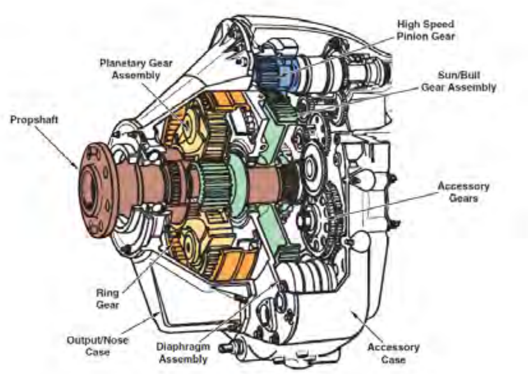

Figure 3. Reduction Gearbox

The engine torque sensor gear assembly measures the engine output torque created by the angular displacement between the engine main shaft and the torsion shaft, which occurs when the engine is driving the propeller. The torque sensor converts the angular displacement into a proportionately metered oil pressure. This metered oil pressure is utilized as an input signal to the aircraft torquemeter, to provide torque value indication.

[2] TSG134

ASSESSMENT OF ACCIDENT ENGINE

The engine was a Honeywell TPE331-10R-511C, Part Number 3102170-6, serial number (S/N) P42145C. The engine was converted and overhauled on April 26, 2010 and installed on the airplane on July 7, 2010. According to the logbook, the engine total time since overhaul was 295.3 hours; the number of cycles since overhaul was estimated at 186 because the last cycle count was not entered in the logbook.[3]

During disassembly, it was noted that rotation of the power section produced a corresponding rotation of the fuel pump/oil pump drive gear through the direct drive fuel control gear train (DDFC), Figure 4. This showed that the gear train from the main shaft spur gear to the fuel pump drive gear was intact. The importance of this finding will be discussed in greater detail in a subsequent section of this report.

Figure 4. DDFC Gear Train

[3] NTSB Powerplant Group Chairman's Factual Report

Evidence of rotational signatures within the engine were noted in the following locations:

- Rotational scoring to the propeller shaft (Figure 5 & Figure 6) with corresponding rotational scoring to the inner bore of the sun gear (Figure 7 & Figure 8).

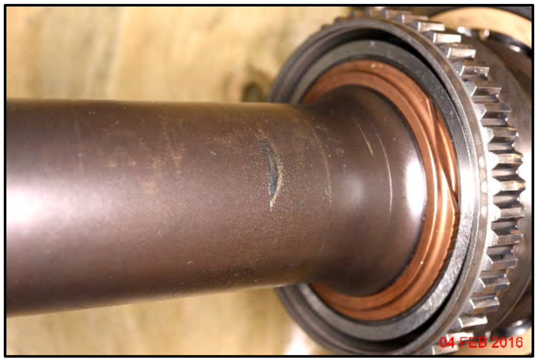

Figure 5. Propeller Shaft

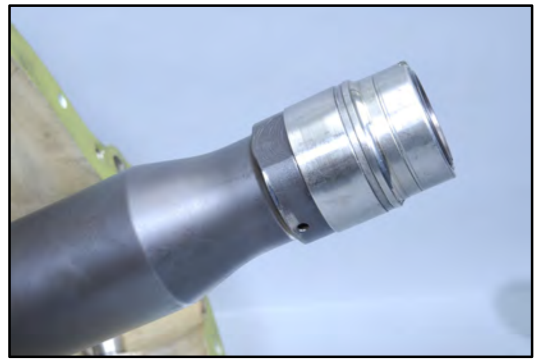

Figure 6. Propeller Shaft

Figure 7. Sun Gear

Figure 8. Sun Gear, Forward Looking Aft

- The separated starter/generator drive splines remained within the gear splines (Figure 9), (the separation is consistent with the sudden stoppage of the propeller).

Figure 9. Starter/Generator Drive Shaft

- The torsional overload separation of the torsion shaft (Figure 10), which is consistent with the sudden stoppage of the propeller.

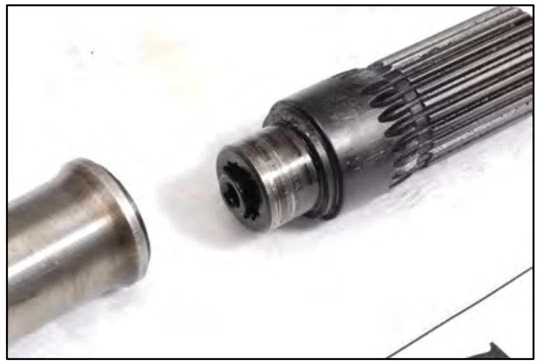

Figure 10. Torsion Shaft

  - During removal of the torsion shaft from the engine (Figure 11), it was noted that the aft bushing was not intact on the torsion shaft and appeared to have disintegrated. No fragments of the bushing were specifically identified or collected. Any and all debris from the accident engine was returned with the engine upon the NTSB's release with the exception of any waste oil/fuel collected in the drip tray beneath the teardown stand. This was disposed of in accordance with Honeywell's HAZMAT disposal plan with the NTSB's approval.

Figure 11. Torsion Shaft

- Rotational scoring damage (rub) was noted to the first stage compressor impeller shroud inducer and exducer areas (Figure 12) with corresponding scoring to the first stage compressor impeller (Figure 13 & Figure 14).

Figure 12. First Stage Compressor Shroud

Figure 13. First Stage Compressor Impeller

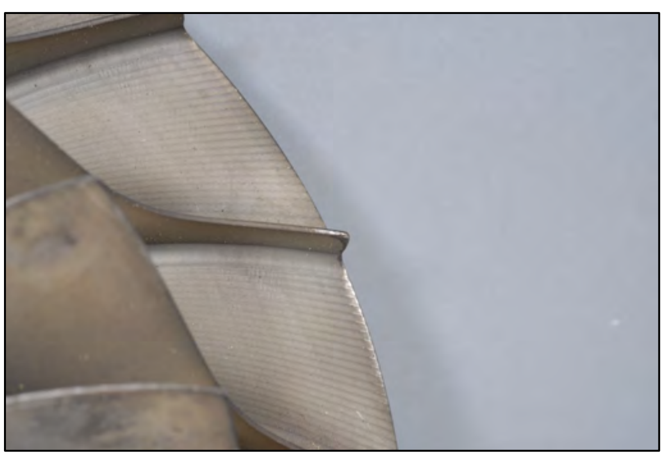

Figure 14. First Stage Compressor Impeller

- Rotational scoring damage (rub) was noted to the second stage compressor impeller shroud at the inducer and exducer areas (Figure 15 & Figure 16) with corresponding scoring to the second stage compressor impeller (Figure 17).
    - o Light static contact marks were noted on the second stage compressor impeller shroud. The static marks were on top of the rub indications which evidences that they occurred after impact and the engine had spooled down.

Figure 15. Second Stage Compressor Shroud

Figure 16. Second Stage Compressor Shroud

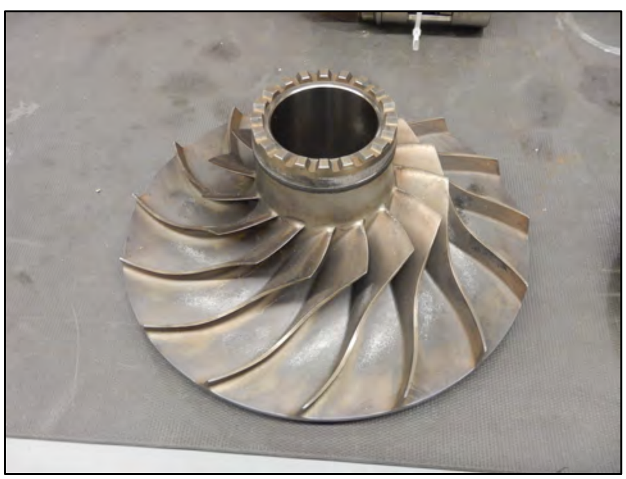

Figure 17. Second Stage Compressor Impeller

- Rotational scoring damage to the first stage compressor impeller aft hub (Figure 18) with corresponding rotational scoring damage to the crossover duct seal area (Figure 19).

Figure 18. Aft Hub of First Stage Compressor

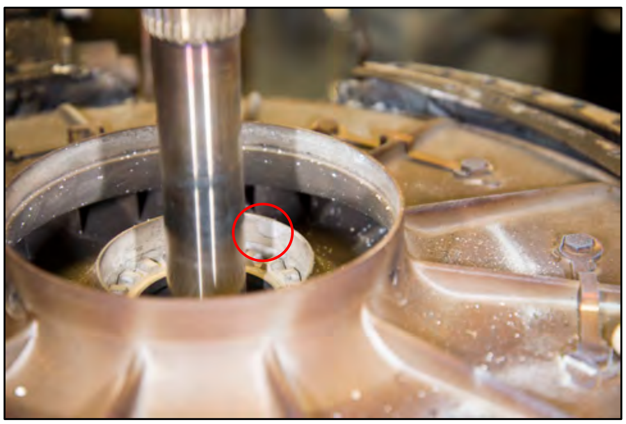

Figure 19. Crossover Duct Seal Area

- Rotational scoring damage to the second stage compressor impeller forward hub (Figure 20) with corresponding rotational scoring damage to the crossover duct seal area (Figure 19).

Figure 20. Second Stage Compressor Impeller Forward Hub

- Ingested debris was noted within the second stage compressor diffuser (Figure 21), de-swirl vane assembly (Figure 22) and combustor liner (Figure 23).

Figure 21. Second Stage Compressor Diffuser

Figure 22. De-swirl Vane Assembly

Figure 23. Combustion Liner

- Rotational scoring to the first stage turbine rotor blade tip shroud segments (Figure 24) with corresponding rotational scoring damage to the first stage turbine rotor blades (Figure 25).

Figure 24. First Stage Turbine Blade Tip Shroud Segments

Figure 25. First Stage Turbine Rotor Blade Tips

Evidence of operational signatures within the engine were noted in the following locations:

- Metal spray on the leading edge (Figure 26) and suction side (Figure 27) of the first stage turbine nozzle stator vanes.

Figure 26. Metal Spray on First Stage Turbine Stator Vanes

Figure 27. Metal Spray on First Stage Turbine Stator Vanes

- Metal spray on the leading edge (Figure 28) and suction side (Figure 29) of the first stage turbine blades.

Figure 28. Metal Spray on First Stage Turbine Blades

Figure 29. Metal Spray on First Stage Turbine Blades

- Metal spray on the suction side (Figure 30) of the second stage turbine nozzle stator vanes.

Figure 30. Metal Spray on Second Stage Turbine Stator Vanes

- Metal spray on the pressure (Figure 31) and suction sides (Figure 32) of the second stage turbine blades.

Figure 31. Metal Spray on Second Stage Turbine Blades

Figure 32. Metal Spray on Second Stage Turbine Blades

- Metal spray on the suction side of the third stage turbine nozzle stator vanes (Figure 33).

Figure 33. Metal Spray on Third Stage Turbine Stator Vanes

Metal spray is created during the impact sequence when the rotating impeller(s) come into contact with their respective aluminum coated shrouds. The impellers shave off (rub) the aluminum coating which introduces small aluminum particles into the gas path of the engine. The aluminum particles then enter the reverse flow annular combustion chamber where, in the presence of a flame (i.e. operating engine), they become molten. The molten aluminum particles then impinge upon the downstream rotating and static turbine components, where they form the observed metal spray patterns.

A non-operating engine, i.e. without combustion, will not produce compressor shroud metal spray deposits on the turbine components. A rotating but non-operating engine may produce compressor rubs at impact, but the residual temperature within the engine combustor and turbine is insufficient to liquefy the compressor shroud particulates. The melting point of aluminum is 1220 degrees Fahrenheit. Immediately after combustion in the engine ceases, the metal temperature of the turbine components rapidly drops to less than 400 degrees F[4]. At this temperature, the aluminum particulates will not melt and will not adhere to the turbine components as observed in this engine.

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[4] TPE331-HPT-Vane-Thermal_June_2017_Rev2

ASSESSMENT OF THE PROPELLER

The propeller was a four-bladed Hartzell model HC-B4TN-5NL, S/N 280 with type 10890 blades. It was manufactured on April 27, 2010 and installed on the airplane on July 7, 2010. According to the logbook, the total time since new was 295.3 hours. There was no record of any further servicing[5].

The propeller (Figure 34 and Figure 35) exhibited leading edge tearing and gouging damage to all blades, with 2 blade tips torn and separated. Chordwise scratching was noted to all of the propeller blades. Three of the propeller blades were bent aft and the fourth propeller blade exhibited S-bending. The damage noted is evidence of a powered propeller impacting terrain.

Figure 34. Propeller

Figure 35. Propeller

ADDITIONAL INSPECTIONS

I attended the following additional examinations which did not materially change my position that the engine was rotating, operating and driving the propeller at the time of impact with terrain.

- November 4, 2016 - Component inspection at TAE USA (Kansas City, MO)
- November 10, 2016 - Component inspection at National Flight Services (Holland, OH)
- December 8-9, 2016 - Laboratory inspection at Applied Technical Services (Marietta, GA)

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[5] NTSB Powerplant Group Chairman's Factual Report

- February 1, 2017 - Laboratory inspection at Applied Technical Services (Marietta, GA)

None of the components examined at these inspections exhibited any non-conformance, pre-existing condition, or part failure that was not attributed to the accident.

TORSION SHAFT

The torsion shaft installed in the accident engine was identified with the following markings (Figure 36):

Figure 36. Torsion Shaft

CAGE:	99193-
Part No.:	3101758-6
Serial No.:	SN98P04737
Lot No.:	LN98P064

The first two digits in both the Lot Number and Serial Number indicate that the torsion shaft was manufactured in 1998. The production work order (PWO) for the manufacture of this unit is provided in Appendix A. The unit was one of 15 in the manufacturing lot, which was designated lot 98P064. The PWO is the paperwork traveler that documents compliance with each of the manufacturing operational steps. Each of the operations is defined in the manufacturing operations and tooling (MOT) document, which provides the dimensional, equipment, and inspection requirement for each step. The manufacturing step numbers increase incrementally from Operation No. 10 thru Operation No. 250 as the sequential tasks are completed. Operation 180, a step near final completion, requires the technician to straighten the shaft per sketch (Figure 37), with defined runout limits. Along the length of the shaft, the maximum allowable runout limits vary from .002

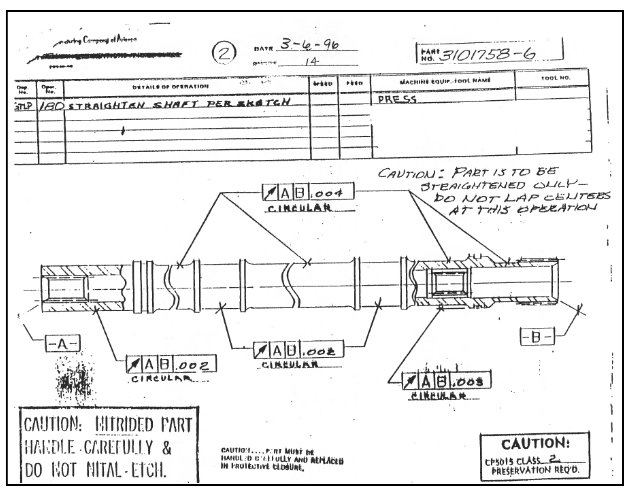

Figure 37. MOT Excerpt

to .004, based on location. Referencing the PWO Operation 180 (Figure 38), the technician selected one of the shafts, inspected the runouts and straightened as required; this is known as the “first piece” as annotated in the 4th column of the PWO. An inspector verified the shaft conformed to the defined requirements and placed a stamp in the 5th column (CO-INSP). An accompanying document, known as detailed inspection instructions (DII) as identified by the letter “D” in the 3rd column, provides the requirements and conformity tracking for each of the parts in the order. After the operator completed the operation for all of the parts on the PWO, a stamp was placed in column 9 showing that the operation was completed and 15 pieces were accepted and none were rejected. An inspector counter-stamped the “D” which verifies the paperwork was compliant. The DIIs are not retained and are not part of the permanent manufacturing records.

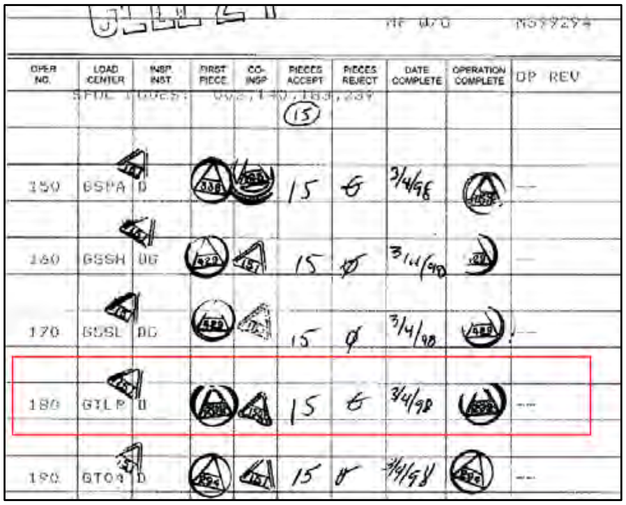
OPER NO.	LOAD CENTER	INSP. INST	FIRST PIECE	CO-INSP	PIECES ACCEPT	PIECES REJECT	DATE COMPLETE	OPERATION COMPLETE	OP REV
					15				
150	6SPA	D			15	0	3/4/98		--
160	GSSH	DG			15	0	3/4/98		--
170	GSSL	DG			15	0	3/4/98		--
180	GTLP	D			15	0	3/4/98		--
190	GTO4	D			15	0	3/4/98		--

Figure 38. PWO Excerpt

Attached to the PWO is the identification and traceability master sheet (last page of Appendix A), which provides the list of all serial numbers that were produced within lot 98P064. SN98P04737 is within the listed range of SN98P04735 thru SN98P04749. All 15 pieces within this lot were found to be conforming and were put into stores.

Honeywell continues to manufacture torsion shafts. Figure 39 shows the straightening press that is used for inspecting and straightening torsion shafts during manufacture. The part installed on the machine is an in-process 3102028 torsion shaft.

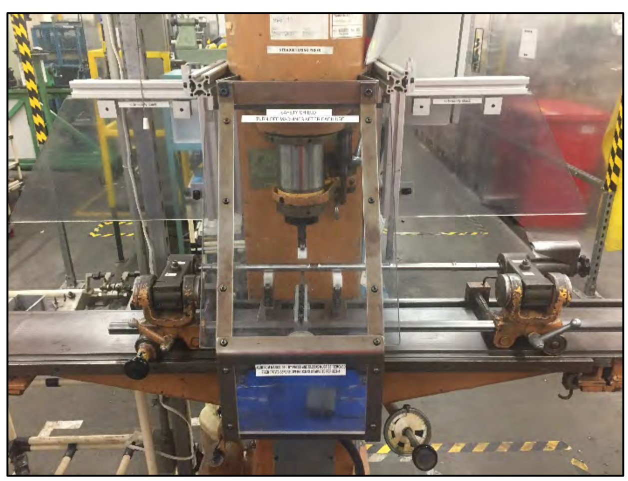

Figure 39. Straigtening Press

According to the engine logbook, torsion shaft SN98P04737 was installed in P42145C on September 14, 1998. The engine logbook entry and FAA Form 8130-3 airworthiness tag (return to service paperwork) are provided in Appendix B. At the time, the engine model TPE331-10UF-513H had accumulated 4147.8 TSN (hours)/4980 CSN (cycles). At that time, the engine was installed on a Jetstream J3101, aircraft registration VH-OZD. According to the logbook, it was later removed on September 25 2001, when the engine had accumulated a total of 4298.3 HSN / 5081 CSN. Before removal, a pre-removal inspection sheet must be completed. This document is provided in Appendix C and did not reveal any "unusual or abnormal condition" during the engine operational checks.

On March 7, 2003, engine P42145C was installed on N651VN, a different J3101 aircraft, and it had accumulated a total time of 4393.1 TSN / 5165 CSN upon removal on October 21, 2003 (torsion shaft TSN 245.3 hours). A subsequent note in the engine logbook states "this logbook closed April 22, 2010" (Appendix D).

A new logbook was established for the engine P42145C. The first entry states that the engine was overhauled (0 TSO / 0 TSO) and converted from a TPE331-10UF-513H to a TPE331-10R-511C model with a total time of 4393.1 TSN / 5165 CSN. The inspection requirements for the torsion shaft at overhaul are contained in the Honeywell Inspection/Repair Manual.

The specific criteria for the torsion shaft inspection in that manual is provided in Appendix E. The runout requirements vary along the shaft from .003 to .004, with the exception of the forward brass bushing land which has a .001 requirement. Once inspected and found to be serviceable, the engine Overhaul Manual (OHM) provides installation instructions for the torsion shaft, which are contained in Appendix F. During the overhaul process at Executive Aircraft Maintenance (EAM), the torsion shaft was inspected and installed in the engine. The documentation verifying compliance to the IRM and OHM is provided Appendix G.

On July 7, 2010, the engine was installed on DeHavilland DHC-3 SN280, N93PC, by Recon Air Corporation. This installation was authorized by Texas Turbine Conversions, Inc. supplemental type certificate (STC) SA09866SC. As of the date of the accident, the engine had accumulated approximately 295.3 hours TSO.

According to the logbooks and other records, the torsion shaft described above had accumulated approximately 540.6 hours since installation in 1998.

POST-ACCIDENT CONDITION OF THE TORSION SHAFT

The diameters and runouts of the torsion shaft were measured at ATS in December 2016 (Figure 40). These runouts provided a gross displacement at the measured locations but do not provide the angular displacement, i.e. which direction is the shaft bent at the measured locations. Subsequently, a laser scan of the shaft was performed to quantify the displacement and direction. Those results showed that the displacement was in the same radial direction along the axial length of the shaft and the bend originated at the aft bushing land. The aft bushing land was distressed and heat affected and showed evidence of material removal and redepositing (Figure 41). The separation at the aft end of the torsion shaft was due to torsional overload; no material defects were noted.

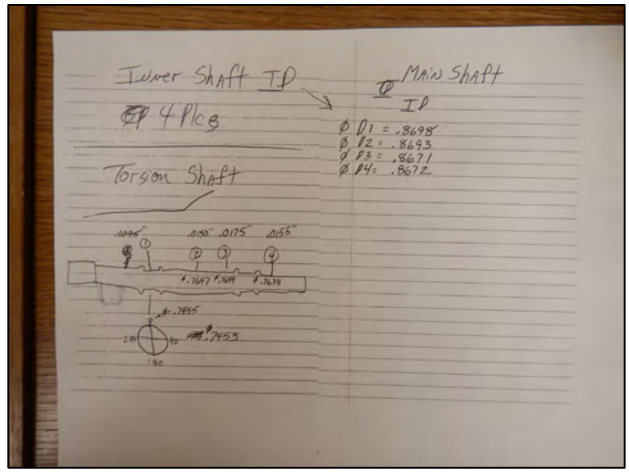

Figure 40. Inspection Results

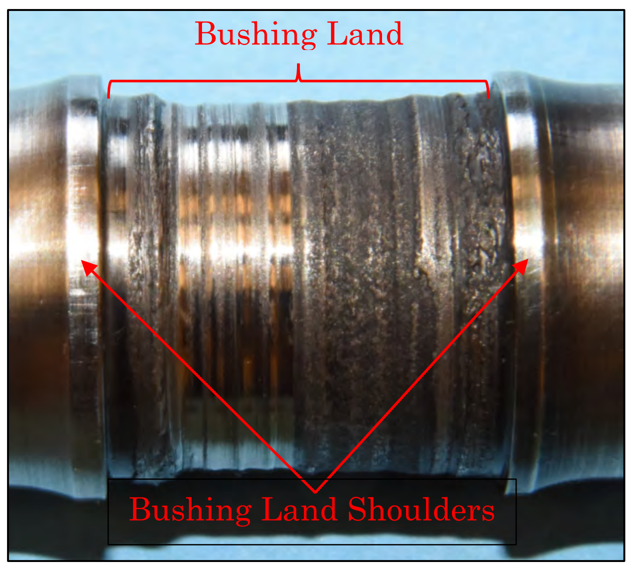

Figure 41. Torsion Shaft Aft Bushing Land

No rotational scoring was noted to the shoulders of the torsion shaft aft bushing land. The lack of scoring to the shoulders shows that the torsion shaft did not contact the main shaft after the torsion shaft separated.

TEST FIT TRIALS

Plaintiff's expert Colin Sommer stated in his deposition that the torsion shaft had to be bent prior to installation in the engine. To see whether the shaft's bend would have been detected during engine assembly, Honeywell utilized the torsion shaft

runout data to perform test fit trials to see whether it would be possible to install a torsion shaft with the same bent condition as the accident shaft into a main shaft.

Test fit trials were conducted to compare the assembly characteristics of two different torsion shaft installations into an exemplar main shaft (PN 3101672-2, SN 4P9737).

The following torsion shafts were utilized:

- {Deformed Exemplar} Torsion Shaft PN 3107158-6, SN 5P-18416, was purposely deformed to approximate the geometry of the accident shaft, PN 3101758-6, SN 98P04737. Dimensional inspection data provided by ESI from the accident shaft was used to define the deformation geometry.
- An additional torsion shaft PN 3101758-6, SN 16P87088, was inspected and found to conform to the blueprint dimensional requirements of interest.

Figure 42 provides a comparison of the geometries of the accident torsion shaft (SN 98P04737), the deformed exemplar torsion shaft (SN 5P-18416) and the conforming torsion shaft (SN 16P87088). Figure 43 shows the test articles.

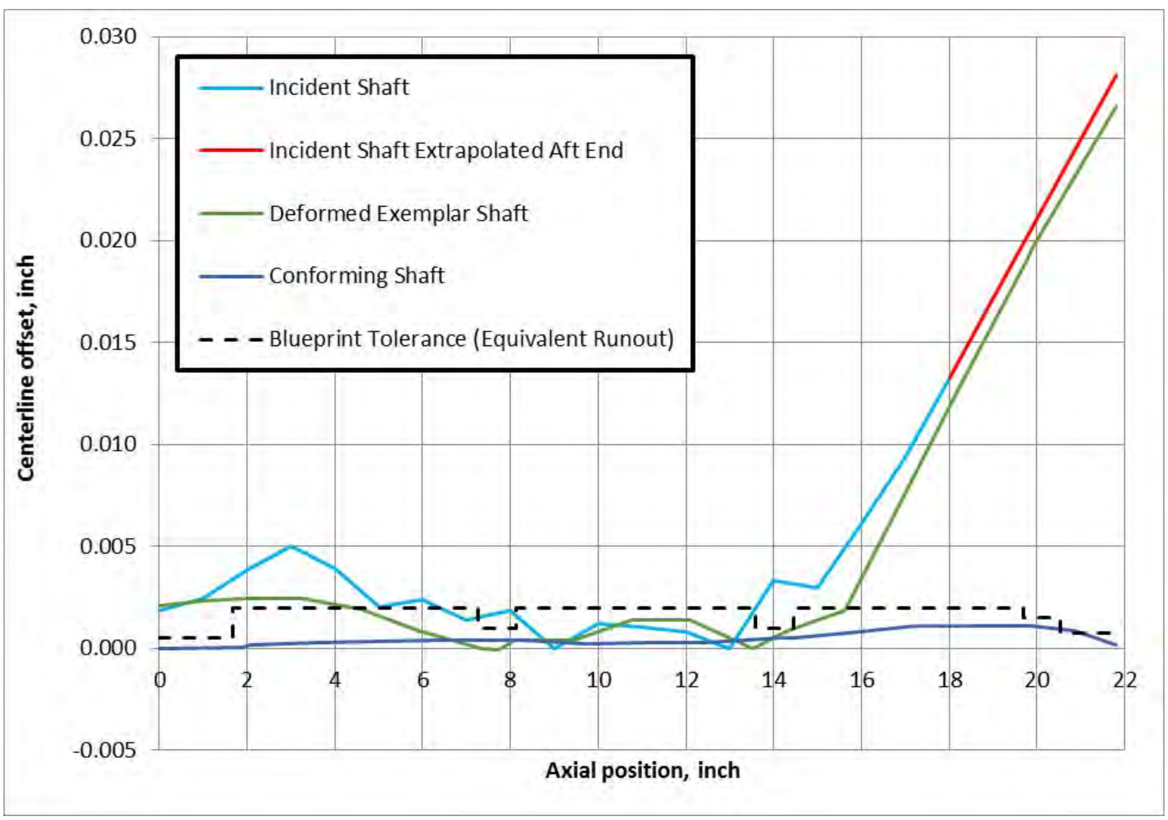

Figure 42. Graphical Comparison.

Figure 43. Test Articles Main shaft (Top), Deformed Exemplar Torsion Shaft (Middle), Conforming Torsion Shaft (Bottom)

Trial Fits[6] and Observations:

Condition under test: without bushings installed on torsion shaft

1. The conforming shaft was installed into main shaft without problem and was diametrically loose.
2. The deformed exemplar shaft was installed into main shaft without problem and was diametrically loose.

Select bushing sizes as required:

1. Vespel bushings, PN 3101703 - The bushing size is selected based on its fit with the inner diameter of the main shaft while it is installed on the torsion shaft. Properly sized bushings will have slight resistance, but will not bind, when inserting the torsion shaft (with bushing installed) into the main shaft. The selection is made from three Vespel bushing sizes, PNs 3101703-7, -8, and -9, each with a progressively larger outer diameter.

2. Bronze bushing, PN 3101759 - The bushing size is selected based on the fit between the bushing outer diameter and the inner diameter of the main shaft. A properly sized bushing will have slight resistance but will not bind when inserted into the main shaft. The selection is made from four bronze

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[6] Honeywell engine maintenance manual 72-00-28 was used as reference for assembly instructions

bushing sizes, PNs 3101759-1, -2, -3, and -4, each with a progressively larger outer diameter. This step is independent of the torsion shaft as each bushing dash number has the same inside diameter, which mates with the forward end of the torsion shaft.

Using these procedures, bronze bushing PN 3101759-4 was selected and Vespel bushings PN 3101703-8 were selected for both the conforming and the deformed exemplar shafts. Additionally, Vespel bushings (2 ea.) PN 866759-1, which do not require size selection, were also selected.

Findings:

1. The conforming shaft with the bushings installed was installed into the main shaft. Slight resistance was noted as prescribed. The bronze bushing end (forward) of the torsion shaft fully installs (Figure 44).

Figure 44. Fully Installed Conforming Torsion Shaft with Bushings Installed, End of Bronze Bushing Moved Slightly Forward for Exhibition

2. The attempt was made to install the deformed exemplar shaft, with the 2 ea. 866759-1 bushings and the aft 3101703-8 bushing installed, into the main shaft. Light resistance was initially noted. As the torsion shaft was installed to the depth of the torsion shaft O-ring land aft shoulder, metal-to-metal contact was noted. The torsion shaft contact with the main shaft prohibited the continued installation of the torsion shaft (Figure 45).

Figure 45. Partially Installed Deformed Exemplar Torsion Shaft with Aft Bushing Installed, Contact with Main Shaft at O-ring Land

Figure 46 illustrates the relative radial mismatch between the deformed exemplar torsion shaft and the main shaft at this point.

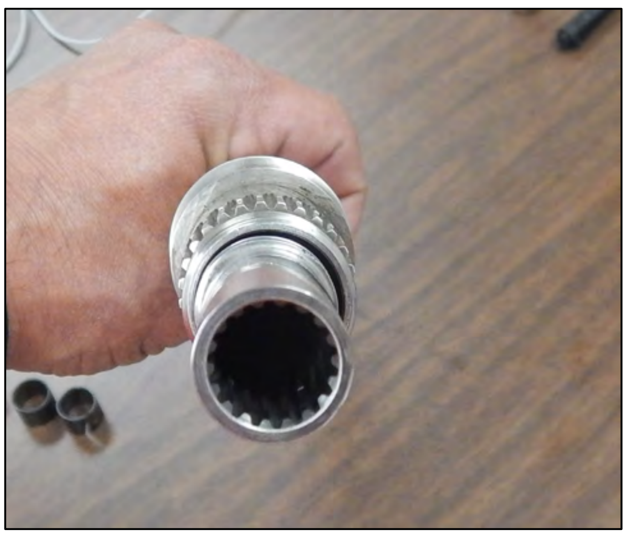

Figure 46. View of Radial Displacement between Main Shaft and Deformed Exemplar Shaft, Aft Vespel Bushing Installed, Bronze Bushing Not Installed

The torsion shaft was manipulated past this point of contact and installed further using force (atypical of the force needed to assemble conforming hardware) and continued metal-to-metal contact resistance was felt between the O-ring land outer diameter and the inner diameter of the main shaft. The mechanic stated that the point at which the torsion shaft initially contacted and hung up would indicate that something was wrong and that he

normally would not have proceeded with the assembly without investigating the cause of the problem. The torsion shaft was further installed using force until the contact reached the bronze bushing location. At that point, the aft edge of the bronze bushing comes into hard contact with the inner diameter of the main shaft opening and the torsion shaft cannot be inserted further without unseating the bronze bushing.

The forward Vespel 3101703-8 bushing was installed and the test fit repeated. As the torsion shaft was inserted into the main shaft up to the forward bushing, it was difficult to get the bushing into the main shaft. After the bushing was installed into the main shaft, significant force was required to continue the installation of the torsion shaft. Once installed to the depth of the bronze bushing, the aft edge of the bronze bushing comes into hard contact with the inner diameter of the main shaft opening. Continued installation of the bronze bushing resulted in metal-to-metal contact with one side of the main shaft ID and the adjacent OD of the torsion shaft.

The test fit with the deformed exemplar torsion shaft was repeated with the smaller OD, 3101703-7 bushings installed, and produced similar results.

The performed test fit confirmed that it is not feasible to install a torsion shaft with the runout dimensions as measured on the post-accident torsion shaft. The forced installation demonstrated is in conflict with the assembly instructions defined in the maintenance and overhaul manuals[7].

TORSION SHAFT WEAR/BEND

The deformed shape of the post-accident torsion shaft is a result of the accident. Upon impact with terrain, the propeller contacted the ground (sudden stoppage) and the torsion shaft separated as documented in Figure 47.

[7] The assembly procedures contained within the maintenance manual and the overhaul manual provide the same instructions.

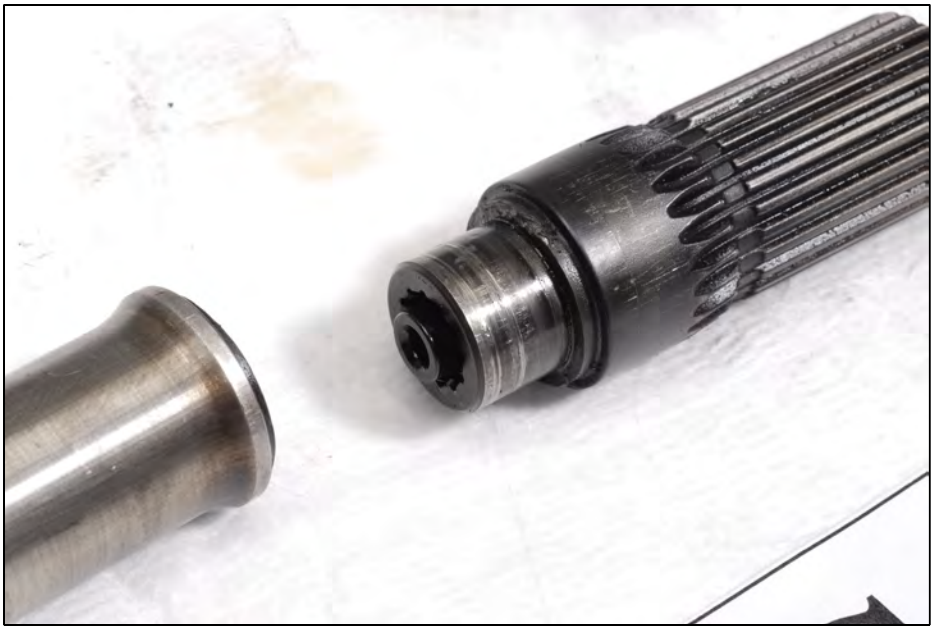

Figure 47. Separated Torsion Shaft

The post-impact bend to the torsion shaft likely occurred for the following reasons:

1. After the torsion shaft fractured at impact, the power section of the engine continued to operate for a period of time, which caused the main shaft to rotate around the now stationary portion of the torsion shaft (forward of the separation) at approximately 43,400 RPM (104%). The aft bushing remained affixed to the inner diameter (ID) of the main shaft and in essence became a journal bearing at the aft bushing ID and torsion shaft outer diameter (OD) interface, which resulted in significant relative rotation. The friction associated with the relative rotation between the two surfaces caused the noted aft bushing land distress. This is evidenced by the localized discolored (heat affected) area at the aft bushing land, the uniformly removed and redeposited shaft material around the circumference of the land, and the total destruction of the aft bushing. The ESI laser scan of the torsion shaft showed an approximate 43% decrease in the nominal wall thickness at the aft bushing land. The localized heating due to friction and the shaft wear are partially responsible for the deformation noted to the post-accident torsion shaft.

2. Additionally, the aft portion of the torsion shaft, including the scavenge pump drive insert, remained engaged within the aft splines of the main shaft and continued to rotate with the main shaft. The turbine scavenge pump drive

shaft remained within the drive insert and continued to scavenge oil from the turbine bearing cavity (Figure 48). Concurrently, the direct drive fuel control gearing (DDFC) was also driving the fuel pump, fuel control unit (FCU) and oil supply and scavenge pumps within the gearbox. Because of this, the turbine bearing continued to receive supply oil while the engine was rotating. Initially, when the scavenge oil exited the scavenge pump drive shaft, it was slung outwards, forward of the drive insert to the ID of the stationary torsion shaft and rotating insert. Capillary action pulled some oil into the interface between the rotating insert and stationary torsion shaft to mitigate some of the wear action at this location. The majority of the scavenge oil flowed in an arc along the bottom of the torsion shaft ID defined by gravity and the volume of oil. The oil within the torsion shaft continued to flow over the aft bushing ID surface and provide localized cooling until the engine power section ceased to rotate. Once the power section stopped, the oil flow from the pump stopped but so had the wear due to the relative rotation. The cooling from the oil along the bottom of the torsion shaft locally lessened the temperature increase from the friction and wear that occurred around at the circumference of the aft bushing land. According to HT 5038, the Honeywell heat treating specification called out on the torsion shaft blue print, AM 355 (the material the torsion shaft is made from) expands during the heat treating process. The temperature exposure at the aft bushing land due to the friction and wear is not known, but the area is definitively heat affected. The thermal delta between the oil cooled area and the remainder of the shaft circumference caused the uneven expansion of the shaft material at the bushing land. The uneven expansion of the shaft material created the permanent deformation (bend) in the shaft, which originated at the wear location.

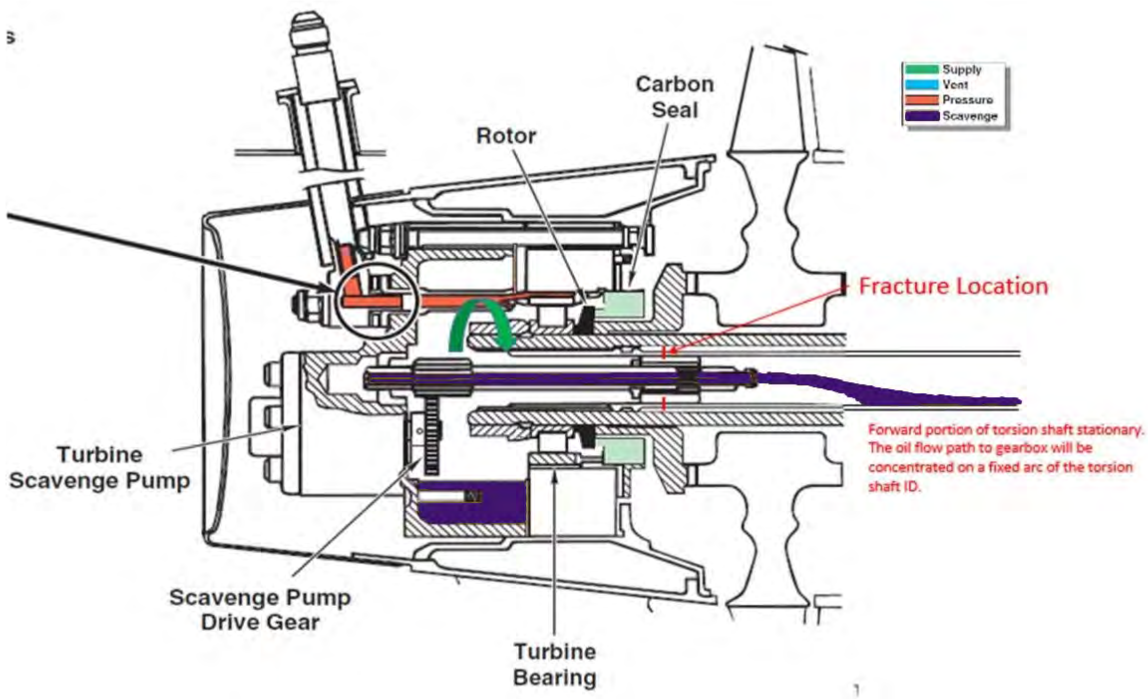

Figure 48. Turbine Scavenge Pump Illustration

The bend could not predate the torsion shaft separation. Plaintiff expert Mr. Sommer opined that the torsion shaft was installed in the engine in its bent condition. This is not consistent with the findings. A bent torsion shaft, i.e. biased to one side of the main shaft ID, would produce locally heavy wear to the area of the torsion shaft bushing land that is opposite the biased direction. The wear to the torsion shaft bushing land is uniform around the circumference. The uniform circumferential wear to the torsion shaft bushing land is conclusive evidence that the torsion shaft was not installed in the engine in a bent condition.

SALVAGE TORSION SHAFT

To investigate whether a torsion shaft could become bent following a propeller strike during an accident, Honeywell procured a salvage torsion shaft from an engine that was known to be operating at the time of impact with terrain. The accident occurred on June 6, 2016 near De Smet, Idaho.

According to the NTSB website[8], "during an aerial application flight to apply fungicide to a wheat field, the pilot was flying the airplane from west to east

[8] https://www.ntsb.gov/_layouts/ntsb.aviation/brief.aspx?ev_id=20160606X24551&key=1

making a spray pass along the south edge of the field, which was bordered by power lines. About 660 ft. from the west end of the field where the pilot started his spray pass, a set of guy wires originated from the top of one of the utility poles that supported the power lines, extended about 65 ft. into the field, and ran directly perpendicular to and in line with the airplane's flight path. However, the pilot failed to maintain clearance with the guy wires, and the airplane's outboard right wing impacted the wires. The airplane subsequently veered right and impacted the power lines, crossed a road that bordered the field on the south, and collided with a stand of trees. The airplane came to rest within the stand of trees about 490 ft. southeast of the initial impact point with the guy wires. Examination of the airframe and engine revealed no evidence of mechanical malfunctions or failures that would have precluded normal operation. Given that the sun was very close to the horizon and would have been almost directly in the pilot's eyes as he attempted to avoid the guy wires, it is likely that sun glare contributed to his difficulty in maintaining clearance from the wires." Post-accident examination identified that the engine power section was no longer connected to the reduction gearbox as a result of the propeller strike, i.e. uncoupled.

The 3102028 torsion shaft (Figure 49) is a different part number than the accident torsion shaft in question but its function is identical. The shaft was separated forward of the aft splines (Figure 50), consistent with torsional overload. The forward bushing land of the salvage torsion shaft exhibited wear indications (Figure 51).

Figure 49. Salvage Torsion Shaft

Figure 50. Salvage Torsion Shaft

Figure 51. Salvage Torsion Shaft

Inspection of the runouts identified that the shaft was bent and the bend originated at the forward bushing land. This further evidences that the deformation is due to the wear at the land and localized heating. Figure 52 provides a graphical comparison of the bends relative to the locations of the bushing lands for both the salvage and accident torsion shafts.

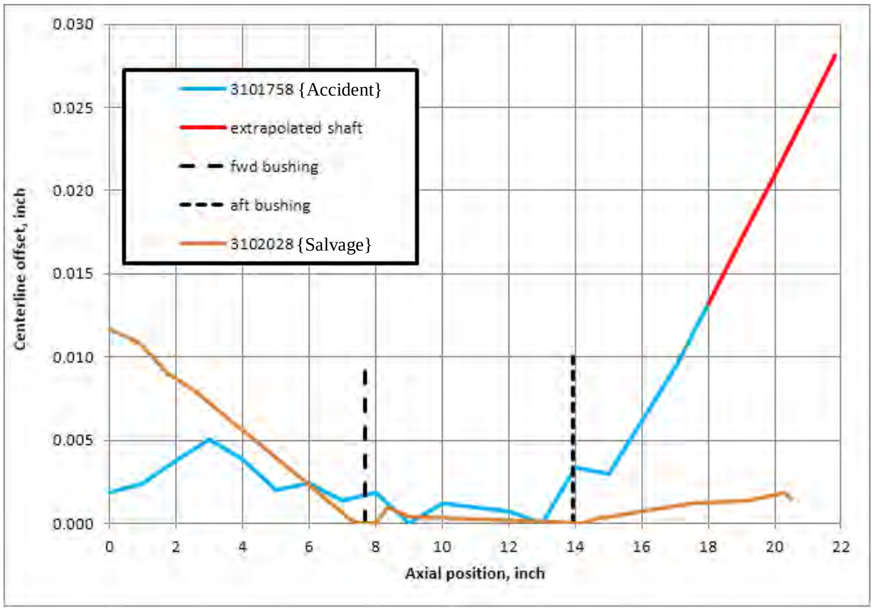

Figure 52. Graphical Comparison of the Torsion Shafts' Deformation

Figure 53. Salvage Torsion Shaft

The salvage torsion shaft separated aft of the oil scavenge pump drive spline insert (Figure 53). Thus, the scavenge pump would not be driven by the operating power section after the propeller strike and uncoupling of the propeller. However, as discussed in the previous section, the DDFC is still driving the fuel pump, FCU and oil supply and scavenge pumps within the gearbox. Thus, the turbine bearing cavity continues to receive supply oil while the engine is rotating. The turbine bearing cavity will fill with oil since the scavenge pump is no longer functioning. Once the oil level in the cavity reaches the height of the gearbox return through the hollow scavenge pump drive shaft, oil will flow through the stationary portion of the torsion shaft. The wear and localized heating at the bushing land coupled with the

differential thermal expansion discussed above, caused the shaft to bend. The condition of the torsion shaft from the De Smet accident engine demonstrates that a torsion shaft in an engine operating at impact can develop a post-impact bend.

TORSION SHAFT CAPABILITY

In his deposition, Mr. Sommer suggested that an erroneous low torque reading might have led the pilot to add power above the engine's torque limit and that the extra torque might have caused the torsion shaft to fracture. Another expert from Honeywell will be providing a report that defines the torsion shaft capability in greater detail. However, in summary, the torsional capability at the initial yield point of the torsion shaft has approximately 1.8x margin in excess of the loads that are imparted by the propeller when producing a maximum engine torque of 900 SHP[9]. The torsion shaft torque level at the maximum operating torque is 1,360 in-lb. Given this load and margin, the engine would need to produce in excess of 2500 SHP in order to begin yielding the torsion shaft.

The TPE331-10R-511C engine installed on the DHC-3 Otter has a maximum exhaust gas temperature (EGT) limit of 565 degrees C. at takeoff[10]. Engine operation is limited at takeoff by either achieving 100% torque (900 SHP) or maximum EGT (595 deg C.), whichever occurs first. Performance limits in the acceptance test procedures for the engine require it to produce a minimum thermodynamic shaft horsepower. The thermodynamic SHP is the HP capability of the engine's power section when operated at maximum permitted turbine inlet temperature at standard sea level conditions. The TPE331-10R-511C thermodynamic SHP is 1000 HP minimum at normal (non-auxiliary power reserve (APR)) takeoff temperature, 100% RPM, sea level static standard day, in the uninstalled condition.

The engine power section is only capable of producing a finite amount of horsepower at the maximum EGT limit. Operation above the maximum EGT will cause

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[9] According to Texas Turbine Conversions, Inc. TTC-FMS-1 AFM Supplement, the engine is flat rated to 900 shp at 1591 rpm.

[10] According to Texas Turbine Conversions, Inc. TTC-FMS-1 AFM Supplement, the maximum permissible temperatures vary as a function of ambient temperature, altitude, and other operating conditions. Takeoff and maximum continuous EGT temperatures are for the ISA standard of 15 C at sea level.

thermal distress and degradation to the turbine components. No thermal distress or degradation was noted to the turbine components from the accident engine.

Additionally, the FCU limits the maximum fuel flow that can be delivered to the engine. This maximum fuel flow is set so that the engine can reach its EGT limit. If the engine is unable to reach the EGT limit, the engine maintenance manual provides allowances to increase maximum power fuel flow through a field adjustment on the FCU. No adjustments to the FCU were noted in the post-overhaul and conversion engine log book.

In summary, the engine is not capable of producing sufficient torque to overload the torsion shaft during normal engine operation. The thermodynamic SHP capability of the power section is also insufficient to overload the torsion shaft. Finally, no evidence, including any squawks, was identified to indicate the engine had been operated beyond its EGT limit or had erratic torque indications.

DIRECT DRIVE FUEL CONTROL OPERATIONAL DESCRIPTION

Plaintiff experts discussed FAA Airworthiness Directive 78-25-08 R3 as being relevant to the investigation. However, the AD is not applicable to the TPE331-10R-511C engine. The purpose of the AD was to install what is known as the direct drive fuel control (DDFC) configuration.

Non-DDFC configurations had a susceptibility to overspeed and subsequent uncontained separations. If the propeller became decoupled as a result of a propeller strike, the fuel control unit (FCU) drive gearing that was connected to the propeller gear train would begin to slow. The FCU would sense the slowing as an underspeed condition (slower than the commanded setting) and would increase the fuel flow to the uncoupled/unloaded power section in attempt to maintain the propeller RPM. This increase in fuel flow could overspeed the power section and cause the separation of the rotating components. The separations could exceed the static structure's containment capability and release high energy fragments from the engine.

The AD required the incorporation of the modified engine fuel control drive train (DDFC) in the reduction gearbox. The DDFC gear train is directly coupled through the torque sensor to the spur gear attached to the front of the main shaft. Should a propeller strike and uncoupling of the propeller occur, the power section would still

become unloaded and increase in RPM. Since the FCU is directly coupled to the power section via the main shaft, the FCU would sense this overspeed condition and limit fuel flow to the engine. The limitation of fuel flow mitigates the risk of a power section overspeed. The FCU will continue to limit fuel flow to the flow required to hold the engine power section RPM at approximately 104%, which is the fuel control unit overspeed governor (OSG) setpoint.

The purpose and functionality of the DDFC configuration is not intended to shut the engine down as opined by plaintiff's experts Mr. Sommer and Mr. Coffman. Its purpose is to prevent the overspeed and uncontained separation of the power section components following the uncoupling of the propeller from the power section. There is no mechanism in the DDFC gear train drive that would interrupt the drive to the fuel pump/FCU and interrupt fuel flow to shut the engine down. As noted previously, post-accident examination of the DDFC gear train showed that it was intact.

During the accident sequence, once the propeller struck the ground and uncoupled the propeller via the torsion shaft separation, the power section of the engine continued to run for a period of time until fuel flow was interrupted.

CONTINUED ENGINE POWER SECTION OPERATION FOLLOWING A PROPELLER STRIKE

The following event is an example of the functionality of the DDFC gear train after experiencing a propeller strike.

> According to the pilot, after he took off for a nearby airport he raised the landing gear but did not raise the 20-degree flaps per the "after takeoff" checklist. Shortly thereafter, when the airplane was at an altitude of about 2,400 feet, and in "heavy rain," the pilot noticed that the right engine was losing power. He subsequently feathered the propeller as engine power reduced to 40 percent, but still did not raise the flaps. Weather, recorded shortly before the accident, included scattered clouds at 500 feet, and a broken cloud layer at 1,200 feet, and the pilot advised air traffic control (ATC) that he would fly an ILS (instrument landing system) approach if he could maintain altitude. After maneuvering, and advising ATC that he could not maintain altitude, the pilot descended the airplane to a right base leg where, about 1/4 nautical mile from the runway, it was approximately 300

feet above the terrain. The pilot completed the landing, with the airplane touching down about 6,200 feet down the 8,000-foot runway, heading about 20 degrees to the left. The airplane veered off the left side of the runway and subsequently went through an airport fence. The left engine was running at "high speed" when fire fighters responded to the scene.[11]

Figure 54 shows the damage caused by left engine propeller strike when the aircraft hit the fence. It also shows the uncoupled propeller draped with the chain link fence. However, as reported by the fire fighters, the power section continued to run.

Figure 54. Millington, TN - ERA09FA083[12]

The examination of the left engine disclosed that the torsion shaft was separated at the aft bushing land, approximately 8.25 inches forward of the aft end of the torsion shaft and forward of the rear Vespel bushing (Figure 55).

Figure 55. Left Engine Torsion Shaft

[11] Downloaded on September 6, 2017 from https://www.ntsb.gov/_layouts/NTSB.Aviation/brief.aspx?ev_id=20081209X62829&key=1

[12] Copied from Honeywell teardown report referenced in Colin Sommer deposition on August 30, 2017; exhibit #13.

TORQUE MEASUREMENT SYSTEM

As stated previously, the TPE331 engine torque sensor gear assembly provides the means for measuring engine output torque. The angular displacement between the engine main drive shaft and torsion shaft, which occurs when load is applied to the engine, causes a lateral displacement of the two torque sensor cam set components. This moves a piston and loads a spring which restricts the flow of system oil through torque sensor metering valve housing ports. The resultant change in oil pressure is proportional to the angular displacement of the shafts. This regulated varying oil pressure is utilized as an input signal to the aircraft torquemeter, to provide torque value indication. Figure 56 provides a general illustration of the torque sensor.

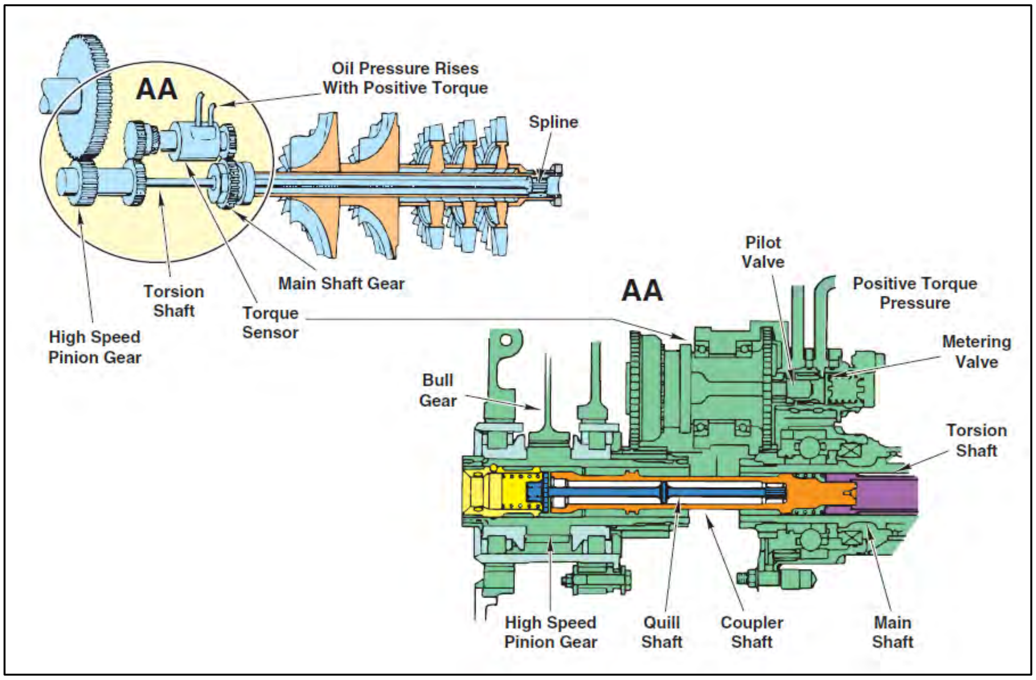

Figure 56. Torque Sensor Illustration

Plaintiff's expert Colin Sommer opined that if the torsion shaft was previously installed in the engine in its current bent condition, the deformation would tend to bind at the aft bushing location and would be apparent as the torsion shaft displaced with the application of load (torque) on the engine, and the torque measurement system would present symptoms of a sticky and iterative response to the application of power rather than the expected smooth and uniform movement of the torque gauge.

Review of the engine and available airframe logbooks did not disclose *any* torque measurement system anomalies during the engine's operational history. This is further evidence that the torsion shaft was not installed in the engine in a bent condition.

SHAFT BOW

Shaft Bow is discussed in the TPE331 Pilot Tips[13]:

- Shaft Bow is known to occur rarely and only after a ground engine shutdown upon completion of flight or high power run-up.
- Following engine shutdown (no forward airspeed), hot-air eddy currents are generated within the static engine.
- With no airflow through the engine, heated internal air rises, leading to a thermal gradient vertically through the engine.
- Cooling starts from the bottom upwards, which causes the main rotating group to be slightly hotter in the upper half, resulting in a slightly bowed shaft.
- In this situation, when the propeller is turned by hand, contact may be noticed between the interstage turbine seals and the stationary abradable seal surfaces.

Shaft bow deflection will be the greatest in the center of the power section at the center curvic coupling because this location is the furthest point away from the bearings (compressor ball and turbine roller) which support the rotating group (Figure 57).

[13] D200405000085, TPE331 Pilot Tips, Recommended TPE331 Operation Procedures, REV 1, 1 Oct 2009

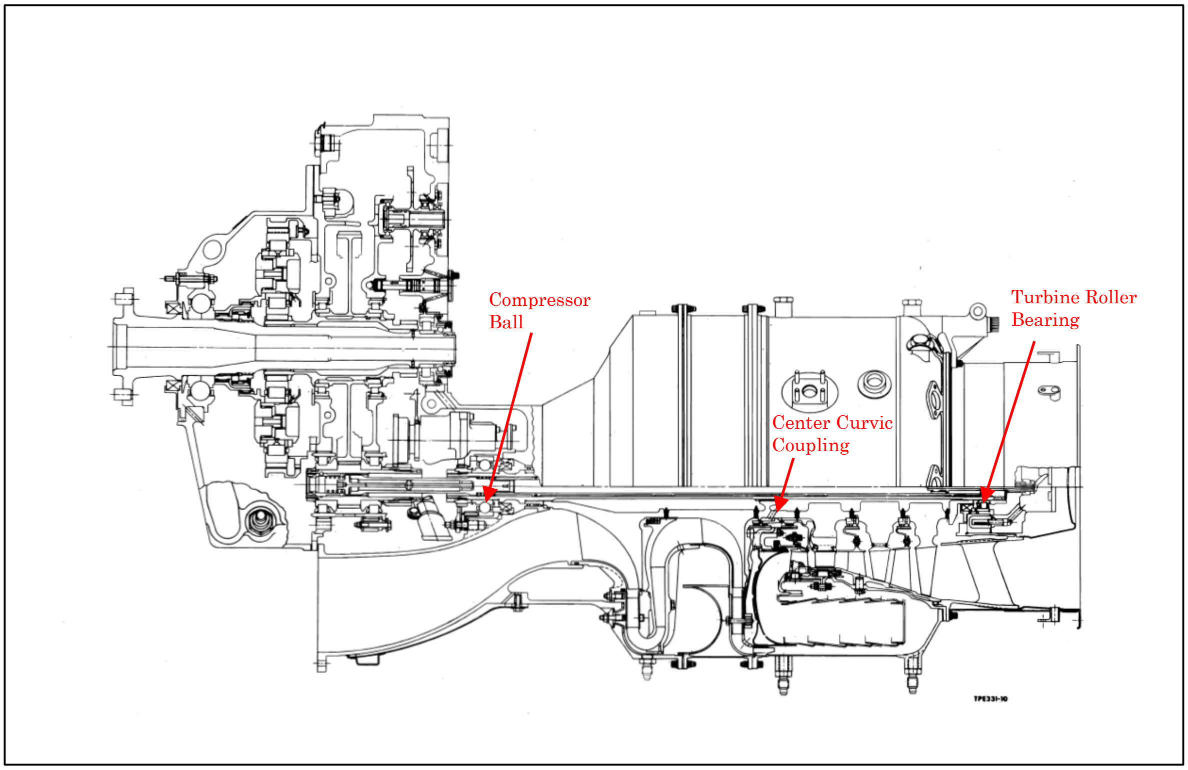

Figure 57. Shaft Bow

No evidence was noted on the center curvic coupling (Figure 58) or the seal area (Figure 59) to indicate that the engine experienced shaft bow operation in the past. Operating the engine in a shaft bow condition will result in a radially offset load and would be evidenced by localized damage to an arc

Figure 58. Center Curvic Coupling

Figure 59. Abradable Seal

of the coupler knife seals and circumferentially uniform damage to the stationary abradable seal. Because of the radial displacement of the shaft, all damage to the static structures within the engine (compressor shrouds, abradable seals, turbine blade tip shrouds, etc.) will be uniform thru 360

degrees and the damage to the rotating components (impellers, rotating seals, turbine rotors, etc.) will be localized in the offsetting direction.

Plaintiff expert Arthur Lee Coffman opined in his deposition that the accident engine had experienced shaft bow operation in the past, which had created the compressor shroud rubs noted in the accident hardware. This scenario is not feasible. The first stage compressor shroud rub is located primarily in one radial direction which is contrary to the signatures that will be produced by shaft bow operation. Shaft bow operation produces circumferentially uniform rubs on the compressor shrouds and localized damage to only a few compressor impeller blades. Additionally, the first stage compressor impeller is located in close proximity to the forward end of the main shaft which is supported by the compressor ball bearing. Consequently, the shaft bow deflection cannot be sufficient to cause the first stage impeller to contact the compressor shroud given the rigid shaft support at this location. Finally, no evidence was present on the curvic coupling or seal, which is the primary contact area when shaft bow operation occurs. For these reasons, the accident engine had not operated with a shaft bow since it had been installed on N93PC after the engine's conversion and overhaul.

EVIDENCE OF A COUPLED ENGINE AT IMPACT

Photographs taken by plaintiff expert Mark Hood during the February 4, 2016 engine examination in Anchorage, Alaska showed the condition of the ring gear support mount dowels (Figure 60). All 4 of the dowels are displaced in the counter-clockwise direction, forward looking aft. Only a coupled engine at impact will produce this damage signature. As the propeller impacts terrain (sudden stoppage), the engine power section is no longer able to transmit all of its energy to the propeller. The excess energy and inertia of the rotating power section caused the planetary gears to

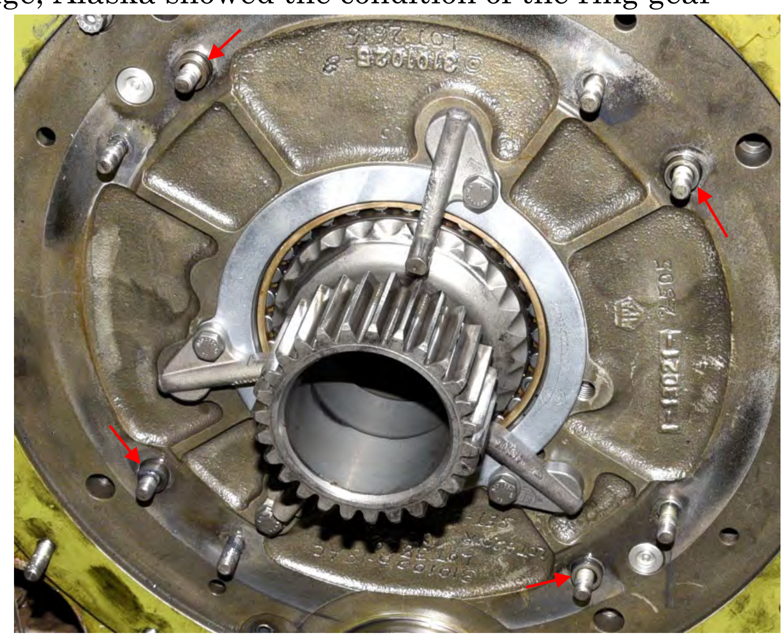

Figure 60. Ring Gear Support Mount Dowels

react against the ring gear, which displaced the steel dowels in the magnesium diaphragm housing. The free-wheeling propeller in an uncoupled engine would only be back driving the reduction gearbox. The inertial energy of the reduction gearbox is not sufficient to displace the dowels.

PROPELLER DISCUSSION

According to the NTSB video study (Figure 61), the aircraft speed was approximately 38 knots at the time the aircraft stalled. The RPM of an uncoupled propeller is solely dependent upon the relative wind driving the propeller and is a function of airspeed.

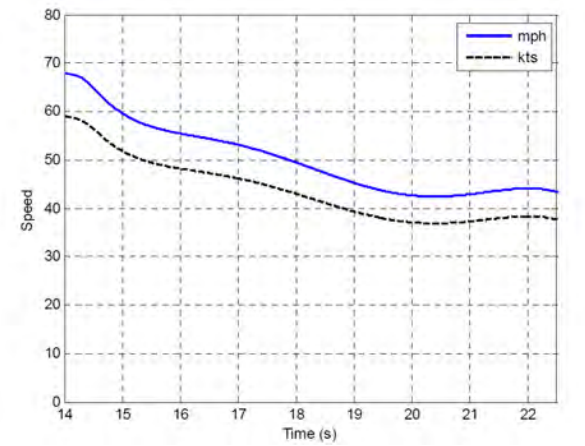

Figure 61. NTSB Video Study

Referencing data for the HC-B4TN-5NL/LT10890N 4 bladed aluminum Hartzell propeller (Figure 62), the estimated RPM of a free-wheeling (uncoupled) propeller would have been less than ½ of the normal 1591 at 100% RPM at an airspeed of 38 knots.

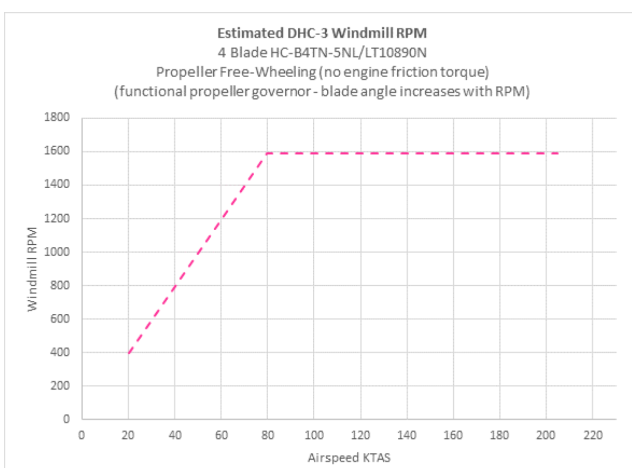

Figure 62. Propeller Speed vs. Airspeed

The accident propeller did not display signatures of low RPM that would be expected if the engine was uncoupled and the relative wind was driving the propeller.

SOUND SPECTRUM

Tom Gabrielson, an acoustics expert on behalf of Honeywell, reviewed the passenger iPhone video footage (IMG_1208.MOV) for the purpose of obtaining engine operational frequency data from the audio portion of the file. Throughout the video, the engine operational frequencies are present up until the point of impact with terrain. As the aircraft begins to stall, variations in engine frequency are noted in Figure 63. The second stage impeller blade passing (15X), power section (N1) and propeller blade rate (PBR) frequencies are displayed as a function of % RPM. All of the frequencies move in sync with one another as a function of time.

Around 53 seconds, as the aircraft continues to pitch up and slow, the propeller blade rate frequency becomes difficult to distinguish. However, prior to impact, the engine power section shows a distinct frequency trace throughout the audio portion of the video. At the time of 60 seconds and continuing until impact, all 3 of the frequency traces in Figure 63 show the engine and propeller stabilized at approximately 96% RPM, which evidences that the pilot had reduced the power lever to flight idle.

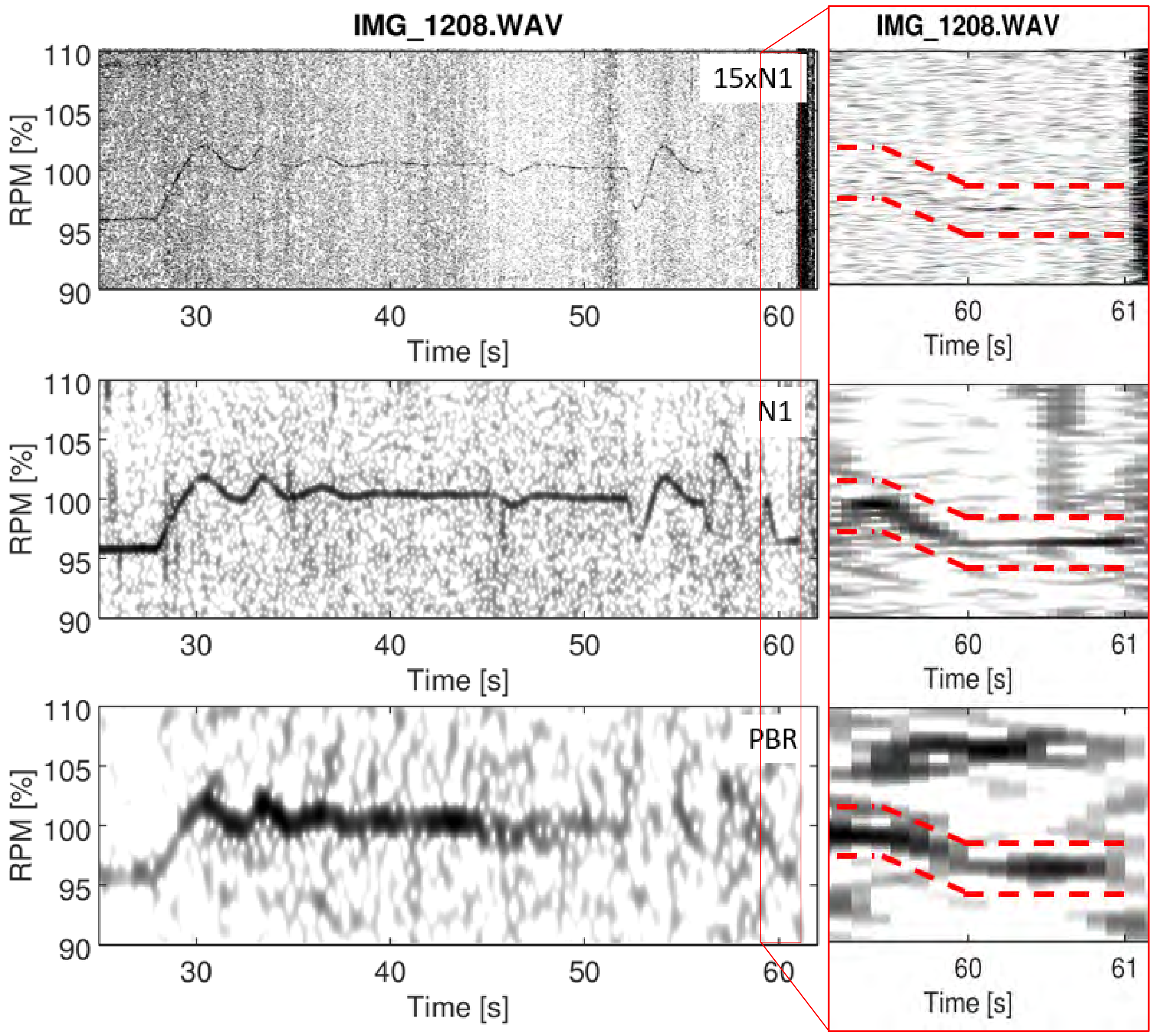

Figure 63. Engine and Propeller Speeds as a Function of Time, Extracted from the Audio Data

It is important to note that the power section does not accelerate and stabilize at 104% (OSG set point) at any point during the accident flight. This provides additional evidence that the propeller remained coupled to the engine and the separation of the torsion shaft occurred at impact. Had the torsion shaft separated in flight as opined by plaintiff experts, the sudden reduction in load would have caused the engine power section to accelerate and stabilize at 104% RPM because of the action of the FCU overspeed governor.

The impact did not significantly damage the structural integrity of the power section, and the engine did not ingest significant debris. These conditions allowed

for the continued operation of the power section of the engine for brief period of time following the initial impact. The first sounds of impact occur at approximately 61 seconds and at approximately 67 seconds the engine power section can be heard spooling down. It is likely that the engine power section stopped operating and spooled down as a result of the loss of fuel being delivered to the engine because of the impact and breach of the aircraft fuel tanks.

The preceding analysis of the sound spectrum from the passenger iPhone 5 video provides empirical evidence that the engine was operating and coupled to the propeller until the aircraft impacted terrain.

FLIGHT TEST

Honeywell, with the assistance of Dr. Gabrielson and Dr. Winn, performed flight testing in an aircraft similarly equipped to N93PC to gather operational audio and video signatures and compare those results with the accident video signatures. In addition to other audio and video equipment, Honeywell utilized an Apple iPhone 5 to record the flight test. Dr. Gabrielson will also be providing a report with greater detail and analysis.

Honeywell performed a power-on stall sequence (wings level, flaps full[14]). The sound spectrum for this flight test maneuver is provided in Figure 64. The second stage impeller blade passing (15X), power section (N1) and propeller blade rate (PBR) frequencies are displayed as a function of % RPM. Similar to the accident video, as the flight test aircraft continues to pitch up and slow, the propeller blade rate frequency becomes difficult to distinguish. Additionally, fluctuations in RPM are also apparent throughout the power-on stall maneuver. The red vertical line on the figure denotes when the aircraft's right wing stalled and the aircraft rolled to the right.

[14] The NTSB Airworthiness - Factual Report of Group Chairman identified that flaps on the accident aircraft were in the full position.

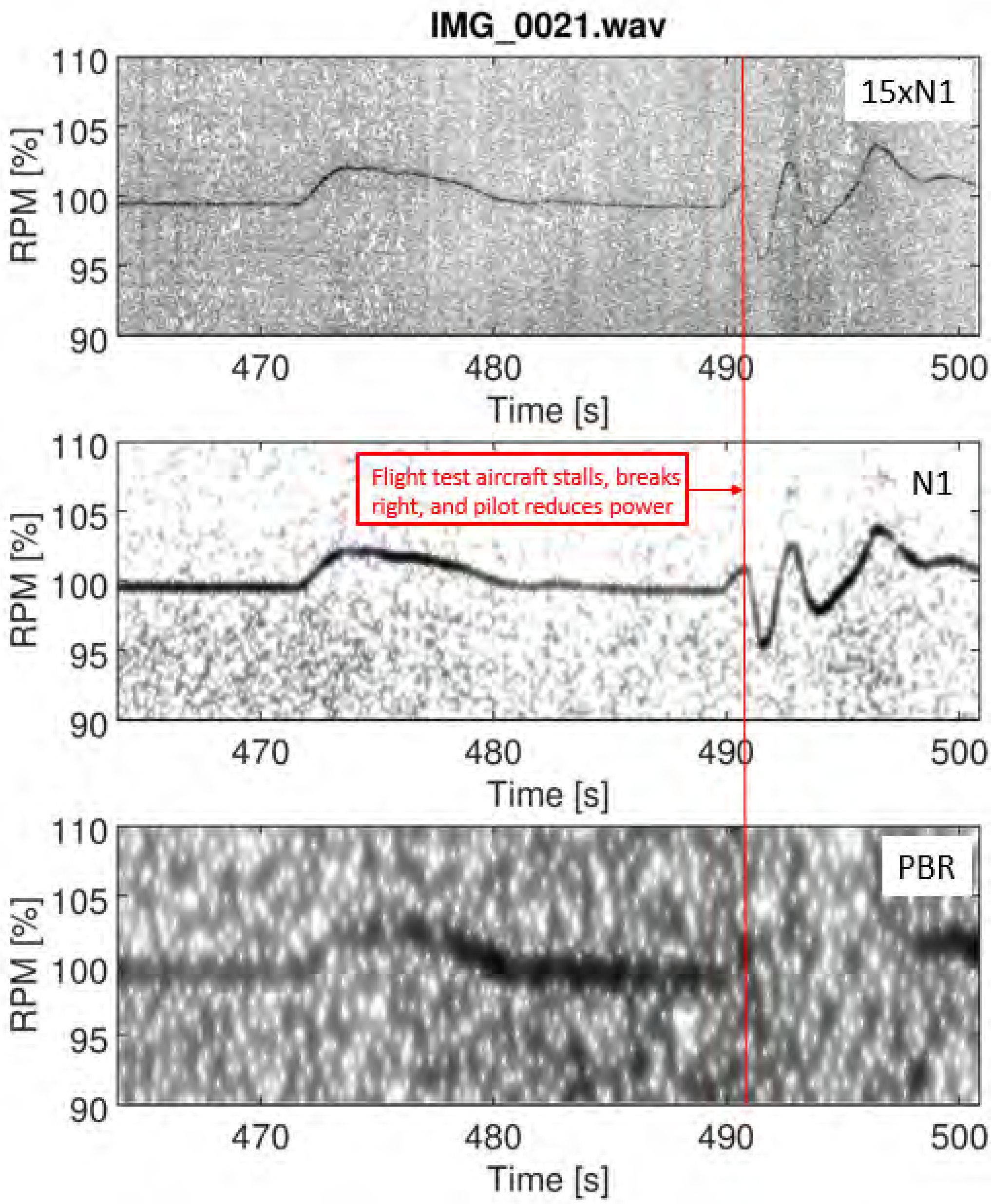

Figure 64. Speed Extracted from the iPhone5 Audio Data during Power-On Stall on 23-Jan-2017

Figure 65 shows a comparison of the engine N1 speed extracted from the accident video with the engine N1 speed extracted from the test flight stall sequence. For clarity, the timeline of the two events have been adjusted to align the speed variations and is denoted by the red line in the figure. The engine speed variations observed in the accident video during the climb and stall (t=52s to 61s) are remarkably similar to the engine speed variations observed in the flight test climb and stall sequence (t=490s to 499s), both in terms of shape and in magnitude. This

suggests that the engine speed variations observed in the accident recording were normal and a response to commanded pilot inputs as captured on the flight test video recording.

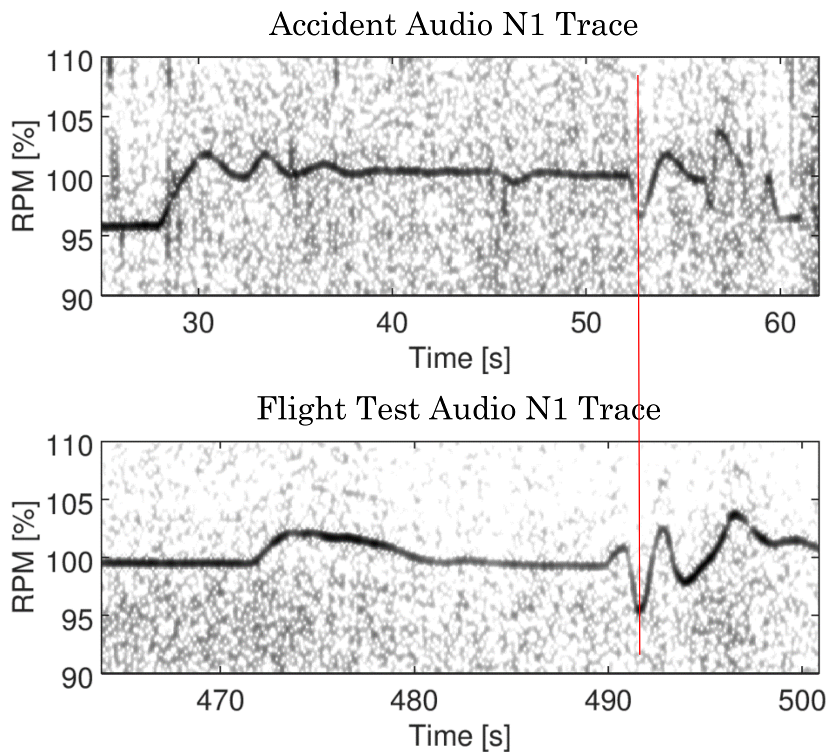

Figure 65. Accident vs. Flight Test Audio Comparison

The flight test also disclosed that when performing a stall *with* power, the aircraft breaks right, rolls approximately 30 degrees and pitches down. Figure 66 provides a reference to the horizon following the break of the right wing.

Figure 66. Horizon Reference after Stall during Flight Test

It was also noted during the Honeywell flight testing that a stall without power (at Flight Idle) would tend to roll the aircraft very slightly to the left once the stall occurred. This data is consistent with the Texas Turbine flight test findings provided in Appendix H. Specifically, the results of Condition 6 [Wings Level (power on, flaps landing)] are in agreement with those experienced during the Honeywell flight test.

During the accident iPhone video, as the aircraft stalls, it rolls to the right until the visual references are no longer in the frame of view. Approximately 4 seconds later, the aircraft impacted terrain in a slightly nose low, right wing low attitude. This factual data is further evidence that the accident aircraft experienced a powered stall.

SDR'S / ACCIDENTS REVIEWED BY PLAINTIFFS EXPERTS

Plaintiffs contend that the torsion shaft fractured in flight, and they provided the following historical incidents to support their position that an inflight torsion shaft failure is possible. A review of these incidents indicates that the only cause of an inflight torsion shaft failure is material defects in the shaft.

It is Honeywell's experience that torsion shaft separations occur as a result of propeller strikes (sudden stoppages). Overload separations of conforming torsion shafts do not occur during normal engine operation. Throughout my career as an air-safety investigator, I have never participated in an investigation that revealed a failure of a torsion shaft as a causal or contributing factor in an accident, incident or service related difficulty (SRD).

<u>Service Difficulty Reports:</u>

1. N150YA, BE124, ESN P27255 on 12/04/2000 – P/N 3102028-2. Not enough information is present within the write-up to determine the cause for the torsion shaft failure, which the SDR says is in the gearbox.

2. N99TF, CASA212CB, ESN P22211 in 1980 – P/N 868605-2. The torsion shaft failed due to a material defect.

NTSB & Other Reports:

3. Sigma Aerospace – The report states that Sigma Aerospace is an authorized Honeywell service center. However, Sigma Aerospace is not qualified or authorized to provide accident/incident investigative analysis and opinions. The Honeywell Product Integrity group is the solely designated organization for accident/incident investigation support.

   There is no indication that the author of the Sigma Aerospace report had background facts, training or knowledge to analyze the cause of the torsion shaft failure. The torsional overload separation of the torsion shaft is consistent with the stated propeller strike. The elongation of the planetary carrier dowel holes documented in the report will only occur when the coupled propeller impacts terrain (see section titled Evidence of a Coupled Engine at Impact). The configuration of the Sigma Aerospace engine is slightly different from the Soldotna engine (2000 RPM vs. 1591 RPM); however, the reaction at the planetary carrier mounts are the same. All of the damage descriptions provided are consistent with an operating, coupled engine impacting terrain. The torsion shaft did not separate in flight.

4. Medicine Lake, Montana (NTSB ID WPR14LA198[15]) – The torsional overload separation of the torsion shaft is consistent with a propeller strike upon impact with terrain. The wear damage to the torsion shaft bushing land is consistent with the continued operation of the power section after the propeller strike and separation of the torsion shaft. Also, the ring gear support mount dowels are displaced counter-clockwise (Figure 67), which provides evidence of a coupled engine at impact.

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[15] https://www.ntsb.gov/about/employment/_layouts/ntsb.aviation/brief.aspx?ev_id=20140522X23743&key=1

Ex. A, Page 51 of 104

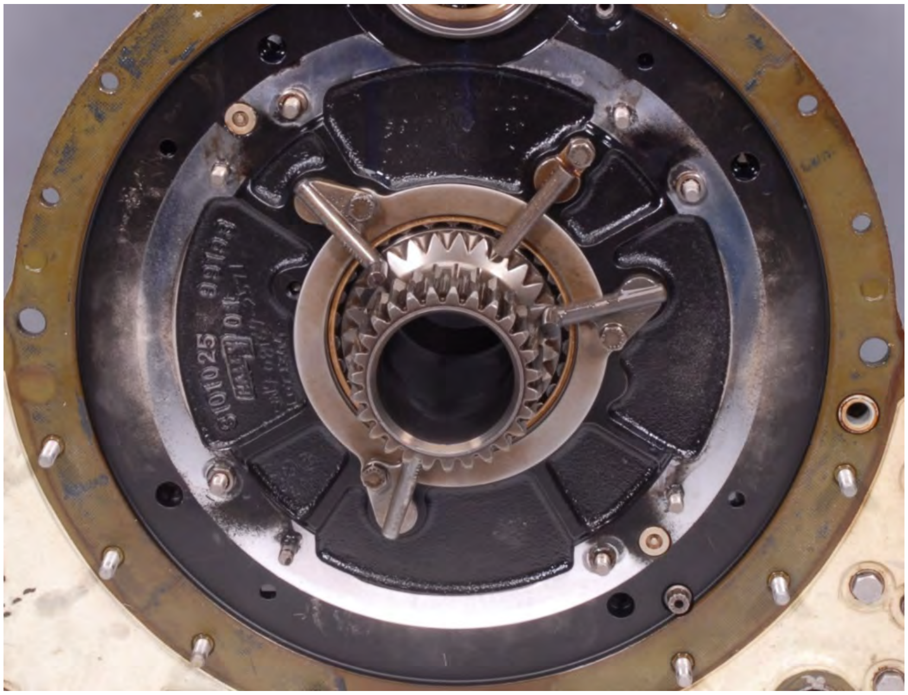

Figure 67. Ring Gear Support Mount Dowels

Additionally, photos of the propeller show leading edge nicks and gouges and forward and aft propeller blade bending (Figure 68). The damage is consistent with an operating engine and coupled propeller impacting terrain.

Figure 68. Medicine Lake Propeller

I concur with the findings stated in the Honeywell teardown report that states, "The teardown and examination of the left engine, S/N P-40320C, revealed that the type and degree of damage was indicative of an engine that was under power and operating at the time of impact. No preexisting condition was found that would have prevented normal operation."

5. Owasso, Oklahoma (NTSB ID CEN14FA046[16]) – I reviewed the NTSB factual report and probable cause for this accident. I also reviewed the information presented in the Honeywell engineering analysis[17].

   The pilot stated that he had a "control problem" and later that he had a "left engine shutdown." During the investigation, the examination of the fuel shut off valve identified that the valve was in the closed position and the manual actuation lever was in the auto position. The valve can be electrically opened and both electrically and manually closed. The electrically closed position of the fuel shut off valve is consistent with the pilot-commanded shut down of the engine.

   The Honeywell engineering analysis discussed the condition of the left engine aft torsion shaft bushing. No damage was apparent to the torsion shaft or the aft bushing. The lack of damage evidenced that the torsion shaft and bushing were not subjected to relative rotation with the main shaft, which would be expected if the torsion shaft separated in flight, as opined by plaintiffs. The feathered propeller impacted terrain, caused the sudden acceleration of the propeller and torsional overload of the torsion shaft.

HISTORICAL ACCIDENTS

Honeywell has participated in investigations involving TPE331 engines that show similar impact damage to the accident engine in question. All of the following examples were found to be rotating, operating and coupled to the propeller upon impact with terrain. They have been divided into two main categories: 1.) Engines with rotational and operational signatures similar to those in the Soldotna engine, and 2.) Engines that experienced a torsion shaft separation upon impact, the power

[16] https://www.ntsb.gov/GILS/_layouts/ntsb.aviation/brief.aspx?ev_id=20131110X03324&key=1

[17] Included in Exhibit #13 from Colin Sommer deposition on August 30, 2017.

section continued to run for a brief period after impact and the torsion shaft experienced relative rotation with the main shaft. These examples provide evidence that the signatures and damage noted in the accident engine are not unique and are consistent with a rotating, operating and coupled engine impacting terrain.

1. Engines with similar rotational and operational signatures:

    - Delaplaine, Arkansas (NTSB ID: CEN15LA259[18]) – The teardown and examination of the engine, S/N P-92108C, revealed that the type and degree of damage was indicative of an engine that was rotating and operating at the time of impact. No pre-existing condition was found that would have prevented normal operation. The engine was generally intact, displayed compressor shroud rubs and metal spray deposits on the turbine stators and rotors. The torsion shaft was separated ~1.2" from the aft end. Representative photos are provided in Figure 69 - Figure 73.

[18] https://www.ntsb.gov/_layouts/ntsb.aviation/brief.aspx?ev_id=20150608X10557&key=1

Figure 69. On-Scene Aircraft

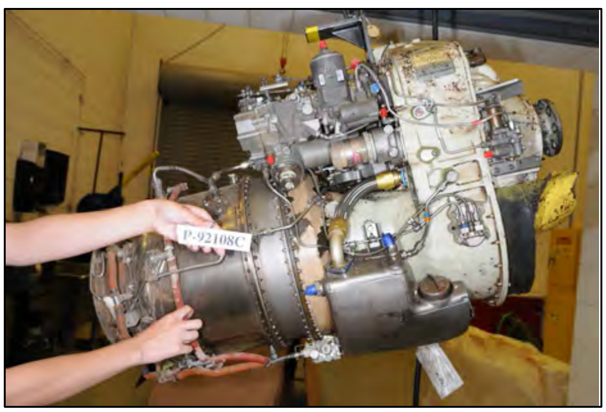

Figure 70. Overall Engine

Figure 71. Compressor Shroud

Figure 72. Compressor Impeller

Figure 73. Metal Spray

- Nashville, Pennsylvania (NTSB ID: ERA12FA120[19]) – The teardown and examination of the left engine, S/N P-77532C, revealed that the type and degree of damage was indicative of an engine that was under power and operating at the time of impact. No preexisting condition was found that would have prevented normal operation. The engine was generally intact, displayed compressor shroud rubs and metal spray deposits on the turbine stators and rotors. The torsion shaft was separated forward of the aft splines. Representative photos are provided in Figure 74 - Figure 78.

Figure 74. On-Scene Aircraft

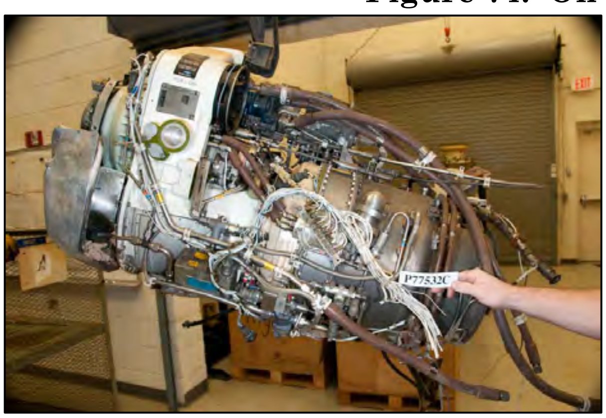

Figure 75. Overall Engine

Figure 76. Compressor Shroud

[19] https://www.ntsb.gov/_layouts/ntsb.aviation/brief.aspx?ev_id=20111222X05125&key=1

Figure 77. Compressor Impeller

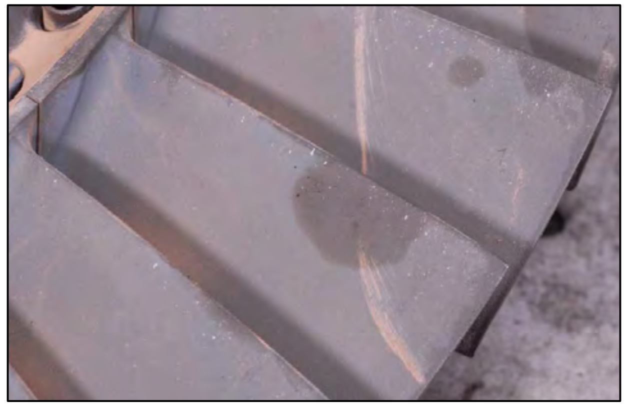

Figure 78. Metal Spray

- Iliamna, Alaska (NTSB ID: ANC15FA071[20]) – The teardown and examination of the engine, S/N P123168, revealed that the type and degree of damage was indicative of an engine that was under power and operating at the time of impact. No pre-existing condition was found that would have prevented normal operation. The engine was generally intact, displayed compressor shroud rubs and metal spray deposits on the turbine stators and rotors. Representative photos are provided in Figure 79 - Figure 83.

Figure 79. On-Scene Aircraft

[20] https://www.ntsb.gov/_layouts/ntsb.aviation/brief.aspx?ev_id=20150915X52520&key=1

Figure 80. Overall Engine

Figure 81. Compressor Shroud

Figure 82. Compressor Impeller

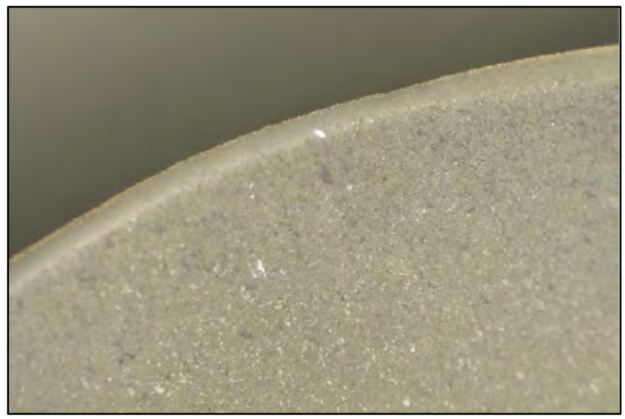

Figure 83. Metal Spray

The preceding three accidents show that low speed/low energy crashes can cause minimal contact between the rotating and stationary structures in the engine, which results in minimal rub signatures.

2. Engines that experienced a torsion shaft separation upon impact, the power section continued to run for a brief period after impact and the torsion shaft experienced relative rotation with the main shaft.

   - Bishop, California (NTSB ID: LAX02FA251[21]) – The torsion shaft from the right engine (P-06184) separated just forward of the aft splines consistent with torsional overload. The torsion shaft also separated at

[21] https://www.ntsb.gov/about/employment/_layouts/ntsb.aviation/brief2.aspx?ev_id=20020819X01425&ntsbno=LAX02FA251&akey=1

the aft bushing location due to the relative rotation and rotational scoring between the torsion shaft and the Vespel bushing. The forward bushing land also exhibited rotational scoring and wear. Similar to the accident engine in question, the power section continued to operate for a period of time after the propeller strike. Representative photos are provided in Figure 84 - Figure 87.

Figure 84. Torsion Shaft

Figure 85. Torsion Shaft

Figure 86. Aft Bushing Land

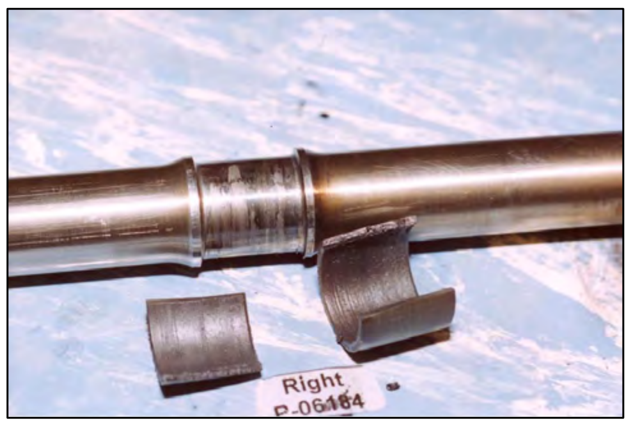

Figure 87. Forward Bushing Land

- Goldsboro, Maryland (NTSB ID: IAD80FA019[22]) – The torsion shaft from the right engine (P-06051) separated just forward of the aft splines consistent with torsional overload. The torsion shaft also separated at the aft bushing location due to the relative rotation and rotational scoring between the torsion shaft and the Vespel bushing. The forward bushing land also exhibited rotational scoring and wear. Similar to the accident engine in question, the power section continued

[22] https://www.ntsb.gov/_layouts/ntsb.aviation/brief.aspx?ev_id=32365&key=0

to operate for a period of time after the propeller strike separated the torsion shaft. Representative photos are provided in Figure 88 - Figure 91.

Figure 88. Torsion Shaft

Figure 89. Torsion Shaft

Figure 90. Aft Bushing Land

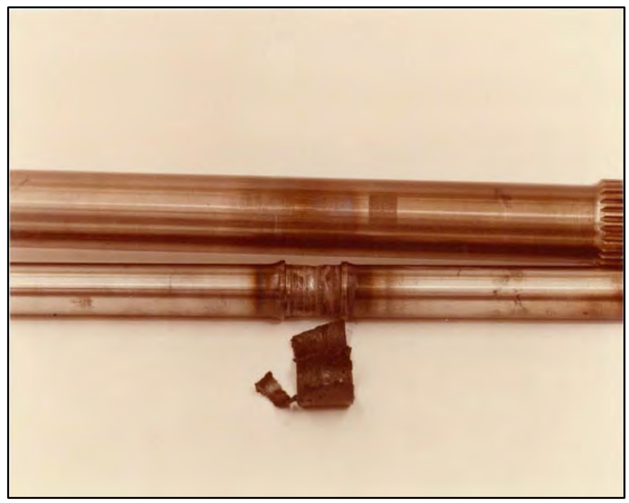

Figure 91. Forward Bushing Land

- Medicine Lake, Montana (NTSB ID: WPR14LA198[23]) – The torsion shaft from the engine (P-40320C) separated just forward of the aft splines consistent with torsional overload. The forward bushing land and shoulders exhibited significant rotational scoring and wear due to the relative rotation between the torsion shaft and the Vespel bushing and main shaft. Similar to the accident engine in question, the power

[23] https://www.ntsb.gov/_layouts/ntsb.aviation/brief.aspx?ev_id=20140522X23743&key=1

section continued to operate for a period of time after the propeller strike separated the torsion shaft. Representative photos are provided in Figure 92 - Figure 93.

Figure 92. Torsion Shaft.

Figure 93. Torsion Shaft Forward Bushing Land

OPINIONS

1. The engine was rotating and operating at the time of impact with terrain.

2. The engine was coupled to the propeller until impact with terrain.

3. The damage to the propeller is evidence of a powered propeller impacting terrain.

4. No pre-existing conditions, non-conformances, or part failures were identified that would have affected the operation of the engine or propeller.

5. Manufacturing records (PWO) confirmed that the torsion shaft features and dimensional characteristics conformed to the production instructions and inspection requirements (MOT/DII).

6. EAM overhaul records confirmed that the torsion shaft was inspected and met the IRM requirements for return to service in an overhauled condition (0 TSO) at the time the engine was overhauled and converted.

7. No operational anomalies with the torsion shaft were identified during its approximate 540.6 hours in service, since installed in 1998.

8. The torsional overload separation of the torsion shaft was the result of the propeller strike at impact.

9. The wear to the torsion shaft aft bushing land was the result of the brief continued operation of the power section following the separation of the torsion shaft at impact.

10. The post-accident condition (bend) of the torsion shaft is the result of the wear and differential thermal heating caused by the relative rotation between the aft bushing and the torsion shaft, which occurred following the separation of the torsion shaft.

11. It is not feasible to install a similarly bent [to that of the accident] torsion shaft into a main shaft.

12. The torsion shaft was not installed in the engine in its post-accident bent condition.

13. The inspection of a salvage torsion shaft showed similar bending that originated at the worn forward bushing land. This further supports opinion 10.

14. The engine is not capable of producing enough horsepower to overload the torsion shaft to failure during normal operation.

15. The accident engine had not operated with shaft bow since it had been installed on N93PC after the engine's conversion and overhaul.

16. The sound spectrum from the accident video showed that the pilot reduced the power lever to flight idle approximately 1.5 seconds before impact. At impact, the engine/propeller RPM was 96% and flight idle torque (power).

17. The power section can be heard spooling down approximately 6 seconds after impact.

18. Honeywell and Texas Turbine flight test confirmed that an aircraft configured with wings level, flaps full, and power-on will roll to the right approximately 30 degrees and pitch down when it stalls. The passenger's iPhone video shows the aircraft stalled and rolled to the right. The on-scene photos show that the aircraft impacted right wing low and slightly nose low. The accident aircraft stalled with the propeller coupled to the engine and with power on.

19. Honeywell does not have a field history of conforming torsion shaft failures in flight.

20. Honeywell does have experience with torsion shaft separations due to impact and subsequent wear of the torsion shaft bushing lands.

21. The damage signatures to accident engines are very dependent upon the terrain they impacts, the angle of impact, the speed of the aircraft, and the speed and power being produced by the engine(s). The damage noted to the accident engine is not unique and is similar to other accident engines that were known to be rotating, operating and coupled with the propeller at impact.

David Studtmann

Appendix A

Production Work Order
(7 pages)

AlliedSignal AEROSPACE

PRODUCTION WORK ORDER

RELEASE	SPLIT	LINE	PART NO.	DESCRIPTION	QTY.	ACCT. NO.	LEADTIME	OUTLINE NO./P.R. REF.
2305	000	44	3101758-6	SHAFT	00015	1212	008	NONE

MIN. PARTS SCHED. QTY. 15 DATE 551

MOT & B.P. REVISION RECORD: B/P 7 MOT DATED 030698 BY FG M-DAY 558 — 2

PAGE 001 OF 14193

MATERIAL INFORMATION

A/C	SIZE	DESCRIPTION	QTY.	AVAIL. INV.	ON ORDER	DUE
1JD	BLANK	3101758-901	15			

SERIAL NO S99294 LOC 3Z 1 1

ADDITIONAL INFORMATION

LOCATION

COMMERCIAL CHG NO 8-2305-03101758-0006

CELL 24

RACK BOXES

SIZE SKIDS

MP W/O MS99294

I.T. REQUIRED --2
METHOD #
R.R #
OR C.M.R. #
LOT #

OPER NO.	LOAD CENTER	INSP. INST.	FIRST PIECE	CO-INSP	PIECES ACCEPT	PIECES REJECT	DATE COMPLETE	OPERATION COMPLETE	OP REV REMARKS
SPOC CODES: 002,140,183,239									
001	Z212	H	—	-	15	0	2/19/98	18490	---
002	Z260		—	-	15	0	2/19/98	18490	--- Cleaned 3/3/98 ~~LETS DETAILS~~
003	V263		—	—	15	0	2/19/98	15	---
040	GTSF	D	J08	B25	15	Ø	2/24/98	A57	---
050	GTSF	D	A87	157	15	Ø	2/24/98	A87	---
060	GTSF	D	J08	986	15	Ø	2/24/98	J08	---
070	~~GLWE~~ GTSF 2-24-98		A58	A51	15	0	2-25-98	A58	---
080	GLMD	D	A12	360	15	Ø	2/25/98	520	---

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PRODUCTION WORK ORDER

RELEASE	SPLIT	LINE	PART NO.	DESCRIPTION	QTY.	ACCT. NO.	LEADTIME	OUTLINE NO./P.R. REF.
2305	000	44	3101758-6	SHAFT	00015	1212	008	NONE

MIN. PARTS SCHED. QTY. 15 DATE 551

MOT & B.P. REVISION RECORD

B/P	MOT DATED	BY	M-DAY	B/P	MOT DATED	BY	M/DAY
V	030696	PG	558				
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PAGE 002 OF
14193

MATERIAL INFORMATION

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SERIAL NO S99294

LOC 3Z 1 1

ADDITIONAL INFORMATION

COMMERCIAL CHG NO B-2305-03101758-0006

CELL 24

MP W/O M599294

LOCATION
RACK BOXES
SIZE SKIDS
I.T. REQUIRED METHOD # --2
R.R # OR C.M.R. #
LOT #

OPER NO.	LOAD CENTER	INSP. INST.	FIRST PIECE	CO-INSP	PIECES ACCEPT	PIECES REJECT	DATE COMPLETE	OPERATION COMPLETE	OP REV
SPOC CODES: 002,140,183,239									
				350	15	0	2/25/98	520	
090	GLMD	D	A12	~~15~~	~~0/15~~	~~0~~	~~2/25/98~~		----
		157							
100	GTLP	D	294	157	15	0	2/26/98	294	----
		157							
110	GTBH	G	250	215	15	0	2/26/98	250	----
120	GTHF	D	432		15	0	3/3/98	432	----
130	V99A	D	—	—	15	0	3/3/98		----
135	Z212		—	—	15	0	3/3/98	A88	----
140	Z260		—	—	15	0	3/3/98	A88	----
145	V263		—	—	15	0	3/3/98		----

REMARKS

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PRODUCTION WORK ORDER

RELEASE	SPLIT	LINE	PART NO.	DESCRIPTION	QTY.	ACCT. NO.	LEADTIME	OUTLINE NO./P.R. REF.
2305	000	44	3101758-6	SHAFT	00015	1212	008	NONE

MIN. PARTS SCHED.		MOT & B.P. REVISION RECORD	B/P	MOT DATED	BY	M-DAY	B/P	MOT DATED	BY	M/DAY	PAGE OF
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MATERIAL INFORMATION

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SERIAL NO S99294

LOC 3Z 1 1

ADDITIONAL INFORMATION

COMMERCIAL CHG NO B-2305-03101758-0006

CELL 24

MP W/O M599294

LOCATION

RACK BOXES

SIZE SKIDS

I.T. REQUIRED METHOD # --2

R.R # OR C.M.R. #

LOT #

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150	GSPA	D 151	338	165	15	0	3/4/98	152	----
160	GSSH	DG 151	429	151	15	∅	3/4/98	429	----
170	GSSL	DG 151	429	151	15	∅	3/4/98	429	----
180	GTLP	D 151	928	150	15	0	3/4/98	928	----
190	GT04	D 151	294	151	15	0	3/4/98	294	----
200	GTHF		432	151	15	0	3/5/98	432	----
210	V954		—	—	15	∅	3/5/98	1887	----
220	C2SP		928	928	15	∅	3/5/98	926	----

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Ex. 67 Page 67 of 104

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PRODUCTION WORK ORDER

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	DATE	551			2							14193

MATERIAL INFORMATION

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SERIAL NO S99294 LOC 3Z 1 1

ADDITIONAL INFORMATION

COMMERCIAL CHG NO B-2305-03101758-0006

MP W/O M599294

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SIZE ___ SKIDS ___

I.T. REQUIRED METHOD # --2

R.R # OR C.M.R. # ___

LOT # LN98P064

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240	Z231		22		15	0	3/5/98	22	----
250	Z206		—	—	15	0	3/6	JT	----

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PRODUCTION WORK ORDER

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MIN. PARTS SCHED. — QTY. 15 — DATE 551

MOT & B.P. REVISION RECORD

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	2						

PAGE 005 OF 14193

MATERIAL INFORMATION

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SERIAL NO S99294

LOC 3Z 1 1

ADDITIONAL INFORMATION

LOCATION

COMMERCIAL CHG NO B-2305-03101758-0006

RACK BOXES

SIZE SKIDS

I.T. REQUIRED METHOD # --2

**TIME STANDARD REF ONLY * MP W/O MS99294

R.R # OR C.M.R. #

LOT #

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OPN	LCTR	DEPT	SC	PCS/HR	SUHR	HRS/PC
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002	Z240	9200		0.00	0.0	0.0000
003	V263	8410		0.00	0.0	0.0000
040	GTSF	4225	D	5.63	2.5	0.1775
050	GTSF	4225	D	5.63	2.5	0.1775
060	GTSF	4225	D	5.46	2.5	0.1830
070	GLWL	4235	D	23.58	2.2	0.0424
080	GLMD	4255	D	15.74	0.6	0.0635
090	GLMD	4255	D	14.36	0.6	0.0696
100	GTLP	4245	E	12.00	0.5	0.0833
110	GTBH	4245	R	7.04	2.0	0.1420
120	GTHF	4245	R	3.14	0.5	0.3182
130	V99A	4245	E	10.00	0.0	0.1000
135	Z212	9200	E	250.00	0.0	0.0040
140	Z240	9200	E	151.51	0.0	0.0066
145	V263	8410	E	250.00	0.0	0.0040
150	GSHA	4225	E	25.00	0.7	0.0400
160	GSSH	4225	E	50.00	0.3	0.0200
170	GSSL	4225	E	30.03	0.5	0.0333
180	GTLP	4245	E	15.50	0.5	0.0645
190	GTQ4	4245	D	19.12	2.0	0.0523
200	GTHF	4245	R	52.91	0.3	0.0189
210	V954	2826	E	20.00	0.0	0.0500
220	C2SP	2826	E	15.01	1.0	0.0666
230	V99A	4245	E	10.00	0.0	0.1000
240	Z231	2826	D	30.03	0.0	0.0333
250	Z206	8800	E	100.00	0.0	0.0100

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DATE	551				2							14193

MATERIAL INFORMATION

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SERIAL NO S99294 LOC 3Z 1 1

ADDITIONAL INFORMATION

COMMERCIAL CHG NO B-2305-03101758-0006

MP W/O MS99294

LOCATION
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SIZE SKIDS
I.T. REQUIRED --2
METHOD #
R.R # OR C.M.R. #
LOT #

OPER NO.	LOAD CENTER	INSP. INST.	FIRST PIECE	CO-INSP	PIECES ACCEPT	PIECES REJECT	DATE COMPLETE	OPERATION COMPLETE	OP REV

REMARKS

**** MATERIAL HANDLING INSTRUCTIONS ****
AT OPERATION 001
WARNING PWO OPER DOES NOT MATCH MOT OPER
WARNING THERE IS MORE THAN ONE LCTR 212 ON PWO
USE MHRC242 WITH INSERT MH24-23-2-11

OPTION FOR SMALL QTYS OF 1 TO 22 PCS:
USE MH2424 WITH INSERT MH24-23-2-11
OR MHV313

THIS IS THE LAST PAGE OF PWO
2305 000 44 3101758-6

3101758-6

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AlliedSignal
AEROSPACE

AlliedSignal Inc.
AlliedSignal Engines
P.O. Box 52181
Phoenix, Az. 85072-2181
Telephone: (602) 231-1000

IDENTIFICATION AND TRACEABILITY MASTER SHEET

PAGE 1 OF 1

P/N 3101758-6
REL 2305 SPLIT 000
QTY 15
P.T. NAME SHAFT

RR OR ITR NUMBER

INITIATOR 1190
INSPECTION
LOT NUMBER LN98P064

SERIAL NUMBER ISSUED SN98P04735 THRU SN98P04749

P/N	LOT	P/N	LOT
3101758-901	LNP049		

SERIAL NUMBER	LOT NUMBER	A	B	C	D	E	F	G	H	I	J	K	L

DISPOSITION
A
B
C
D
E
F
G
H
I
J
K
L

Appendix B

Torsion Shaft Entry into Service
(2 Pages)

ENGINE ☐
MODULE ☐
SERIAL NUMBER

SERVICE RECORD

PAGE

DESCRIPTION OF INSPECTIONS, REPAIRS AND OVERHAULS

ENDORSE ALL INSPECTIONS AND REPAIRS WITH NAME, RATING AND CERTIFICATE NUMBER.

DATE

GARRETT AVIATION SERVICES - HOUSTON

ENGINE TYPE: TPE331-10UF-513H ENGINE S/N: P-42145C TSN: 4147.8 CSN: 4980

THE FOLLOWING INSPECTION(S) AND/OR REPAIR(S) HAVE BEEN ACCOMPLISHED I.A.W. MANUFACTURER'S RECOMMENDED PROGRAM. THIS PROGRAM IS APPROVED UNDER F.A.R. 91.409 PAR. (F) 3. ALL MAINTENANCE PERFORMED I.A.W. THE CURRENT MAINTENANCE MANUALS. ALL LIFE LIMIT CARDS, PARTS INSTALLED, MANUFACTURER'S SERVICE BULLETINS AND AIRWORTHINESS DIRECTIVES ACCOMPLISHED AT THIS VISIT ARE LISTED IN APPROPRIATE SECTIONS OF THIS LOG BOOK. (A C/W INDICATES THE INSPECTION OR ACTION THAT HAS BEEN ACCOMPLISHED),

- C/W Test Cell/Ground Rig Run and S.O.A.P. Sample, C/W Vibration Survey, C/W Lebow Torque Calibration, and C/W Recompensation Run.
- C/W Following Periodic Inspections: C/W 150 hr, C/W 200 hr, C/W 300 hr, C/W 400 hr, C/W 600 hr, C/W 800 hr, and C/W 900 hr.
- C/W Engine Preservation IAW 331 M/M.
- Installed New Fuel Manifold P/N 3102469-2 S/N NSN, New EGT Harness P/N 3103920-1 S/N 982021900242, O/H Ignition Exciter P/N 868962-3 S/N 9407R012, New Coupler P/N 841194-1 NSN, New Quill Shaft P/N 894124-1 NSN, New Torsion Shaft P/N 3101758-6 S/N 98P04737.
- Fuel Nozzles Cleaned and Flowed by Garrett Augusta Reference W/O 59870.

REFER TO THE AIRCRAFT MAINTENANCE MANUAL FOR ENGINE INSTALLATION INSPECTION REQUIREMENTS UPON INSTALLATION.THIS ENGINE HAS BEEN INSPECTED/REPAIRED IN ACCORDANCE WITH THE CURRENT REGULATIONS OF THE FEDERAL AVIATION ADMINISTRATION AND IS APPROVED FOR RETURN TO SERVICE WITH RESPECT TO THE WORK PERFORMED. PERTINENT DETAILS OF WORK PERFORMED ARE ON FILE AT THIS AGENCY UNDER REF. WO. 59006

GARRETT AVIATION SERVICES
FAA REPAIR STATION NO. XB1R606K

DATE 14 September 1998

Wayne C. Delph
HO #30
Wayne C. DELPH.

For details see new Le Bow *Torque Plot* sheet attached in this log book.

SERVICE ENGINE OIL SYSTEM...

DUE TO OIL CHANGE... ANOTHER S.O.A.P. SAMPLE IS REQUIRED IN 25 HOURS TO ESTABLISH A NEW BASELINE.

THIS CERTIFIES THAT THE TYPE OF INSPECTION LISTED AND SIGNED OFF IS IN ACCORDANCE WITH THE MANUFACTURER'S INSPECTION INSTRUCTIONS AS DEFINED IN CURRENT APPLICABLE MAINTENANCE MANUAL.

PX-3107-51 BACK

1. UNITED STATES	2. FAA FORM 8130-3 AIRWORTHINESS APPROVAL TAG U.S. Department of Transportation Federal Aviation Administration	3. System Tracking Ref. No. GAH-98E-0630

4. Organization

GARRETT AVIATION SERVICES
F.A.A./J.A.A. APPROVED REPAIR STATION XB1R606K
17250 CHANUTE ROAD HOUSTON, TEXAS 77205

5. Work Order, Contract, or Invoice Number: 59006

6. Item	7. Description	8. Part No.	9. Eligibility	10. Qty.	11. Serial/Batch No.	12. Status/Work
1	TURBO PROP ENGINE	3102600-6	TBV BY INSTALLER	1EA	P-42145C	SERVICEABLE

13. Remarks

C/W TEST CELL GROUND RIG RUN AND SOAP SAMPLE, VIBRATION SURVEY, LEBOW TORQUE CALIBRATION, AND RECOMPENSATION RUN. C/W PERIODIC INSPECTIONS, C/W ENGINE PRESERVATION, INSTALLED NEW FUEL MANIFOLD P/N 3102469-2 NSN, NEW EGT HARNESS P/N 3103920-1 S/N 982021900242, O/H IGNITION EXCITER P/N 868962-3 S/N 9407R012, NEW COUPLER P/N 841194-1 NSN, NEW QUILL SHAFT P/N 894124-1 NSN, NEW TORSION SHAFT P/N 3101758-6 S/N 98P04737. FUEL NOZZLES CLEANED AND FLOWED BY GARRETT AUGUSTA REFERENCE W/O 59870.

Time Since NEW: : 4147.8 Cycles Since NEW: 4980 Signature: Wayne C Delph HO #30 Date: 14 Sep 98

Limited life parts must be accompanied by maintenance history including total time/total cycles since new.

14. New ☐ Newly Overhauled ☐

Certifies that the new or newly overhauled part(s) identified above, except as otherwise specified in block 13, was (were) manufactured in accordance with FAA approved design data and airworthiness regulations.

NOTE: In case of parts to be exported, the special requirements of the importing country have been met.

19. Return to Service in Accordance with FAA 43.9 ☒

Certifies that the work specified in Block 13 (or attached) above was carried out in accordance with FAA airworthiness regulations and in respect to the work performed the part(s) is (are) approved for return to service.

15. Signature	16. FAA Authorization No:	20. Authorized Signature: Wayne C Delph HO #30	21. Certificate Number: XB1R606K
17. Name (Typed or Printed)	18. Date	22. Name (Typed or Printed): WAYNE C. DELPH	23. Date: 14 SEP 98

FAA FORM 8130-3 (11-93)

USER/INSTALLER RESPONSIBILITIES

It is important to understand that the existence of this Document alone does not automatically constitute authority to install the part/component/assembly.

Where the user/installer work in accordance with the national regulations of an Airworthiness Authority different than the Airworthiness Authority of the country specified in Block 1, it is essential that the user/installer ensures that his/her Airworthiness Authority accepts parts/components/assemblies from the Airworthiness Authority of the country specified in Block 1.

Statements in Block 14 and 19 do not constitute installation certification. In all cases, aircraft maintenance records must contain an installation certification issued in accordance with the national regulations by the user/installer before the aircraft may be flown.

The FAA Form 8130-3 and JAA Form One are equivalent. Other countries such as Canada also have equivalent acceptable documents.

Appendix C

Pre-removal Inspection Sheet
(5 Pages)

13175-0

16161

AlliedSignal
AEROSPACE

RH Rendal

TPE 331

Rental Engine Condition Sheet

Note To be completed at time of removal of the rental engine and returned to the Engine Bank Department, AlliedSignal Inc., Frankfurter Strasse 41-65, 65479 Raunheim, Germany

PLEASE COMPLETE AT TIME OF REMOVAL OF RENTAL ENGINE AND RETURN TOGETHER WITH ENGINE LOG BOOK TO FACILITY FROM WHICH RENTAL ENGINE WAS ISSUED.

RENTAL ENGINE S/N.: P- MODEL TPE331- 10UF-513H

AIRCRAFT TYPE: J3101 A/C S/N.: 668 A/C REG.: VH-OZD

OWNER/OPERATOR: EXECUJET AUSTRALIA

RENTAL ENGINE REMOVED BY (AGENCY/LOCATION: EXECUJET AUSTRALIA
NOTE MUST BE REMOVED BY AUTHORIZED ALLIEDSIGNAL SERVICE CENTER (REF.: SIL NR. P331-049)

RENTAL ENGINE TIME INSTALLED AT: 4147-8 ENG. HRS. 4980 CYCLES DATE 30/5/01

REMOVED AT: 4298-3 ENG. HRS. 5081 CYCLES DATE 25/9/01

OPERATOR
==========

please note that paragraph 2.5 on the attached pre-removal sheet must be COMPLETELY filled out.

This means not only the ACTUAL, but also the REQUIRED data must be annotated.

The REQUIRED data is of utmost importance to our engineers, and failure to fill out this column, may as a consequence, require the engine to be tested at your expense.

Special attention must also be paid to paragraph 4.4.

Any signature other than the one required is not valid.

NOTE:
=====

AFTER RETURN OF RENTAL ENGINE TO ALLIEDSIGNAL, ALL MISSING PARTS WILL BE REPLACED ON CUSTOMER EXPENSE WITHOUT FURTHER NOTIFICATION.

SIGN OFF ACCEPTED	
YES	NO

1.0. PRE-ENGINE RUN CHECK

Item		YES	NO
1.1.	INSPECT ENGINE INLET AND 1st STAGE IMPELLER FOR F.O.D.	JB	
1.2.	INSPECT ENGINE EXHAUST AREA FOR F.O.D. OR OTHER DAMAGE TO 3rd STAGE TURBINE WHEEL, TURBINE SUPPORT STRUTS etc.	JB	
1.3.	PULL ENGINE THROUGH BY HAND AND CHECK FOR FREEDOM OF ROTATION AND VERIFY NO UNUSUAL NOISE.	JB	
1.4.	CHECK OIL TANK QUANTITY AND OIL FILTER BYPASS INDICATOR.	JB	
1.5.	CHECK FUEL FILTER BYPASS INDICATOR		

2.0. GROUND RUN CHECK

NOTE: ALL FLIGHT MANUAL LIMITS, CAUTIONS AND PROCEDURES ARE TO BE OBSERVED.

Item		YES	NO
2.1.	PERFORM GROUND NTS TEST AND NTS LOCKOUT TEST (where applicable) PER FLIGHT MANUAL INSTRUCTIONS.	JB	
2.2.	ENGINE START - PERFORM NORMAL GROUND START AND RECORD:	JB	

POWER SCOURCE		
BATTERIES SERIES	BATTERIES PARALLEL	GROUND POWER UNIT
		X

		YES	NO
	ACCELERATION TIME, LIGHT OFF TO IDLE RPM 35 SECONDS 680 °C PEAK EGT/ITT	JB	
	DESCRIBE ANY USE OF MANUAL SPR NECESSARY TO MAINTAIN CONTINOUS ACCELERATION: NONE REQUIRED	JB	

	ACCEPTED	
	YES	NO
2.3. OVERSPEED GOVERNOR CHECK - VERIFY THAT ENGINE OIL PRESSURE AND TEMPERATURE ARE WITHIN LIMITS THEN PERFORM OVERSPEED GOVERNOR CHECK IN ACCORDANCE WITH FLIGHT MANUAL INSTRUCTIONS. O.S.G. 104 % RPM.	JS	
2.4. TORQUE/TEMP LIMITER CHECK - PERFORM TORQUE/TEMP LIMITER TEST AS PER FLIGHT MANUAL INSTRUCTIONS (where applicable).	JS	
2.5 TAKE OFF POWER CHECK - OBSERVING FLIGHT MANUAL LIMITS, LOAD THE ENGINE TO TAKE OFF POWER AND RECORD: NOTE: THE REQUIRED DATA SHOULD BE PER FLIGHT MANUAL, DEGREE, DAY AND ALTITUDE. O.A.T. 15 °C PRESSURE ALT. 180	JS	

	RPM %	ITT/EGT°C	FUEL FLOW LBS/HR	TORQUE	OIL PRESS. PSI	OIL TEMP.°C
REQUIRED	100.0	[illegible]		104.5	70-120	55-110
ACTUAL	100.0	610	500	104.5	90	80

	ACCEPTED YES	ACCEPTED NO
2.6 ANTI ICE SYSTEM CHECK - AT REDUCED POWER, PERFORM ANTI ICE SYSTEM CHECK IN ACCORDANCE WITH MAINTENANCE MANUAL INSTRUCTIONS (energize for 10 seconds or less and observe EGT/ITT rise)	JS	

3.0 RECORD GROUND IDLE OIL PRESSURE AND TEMPERATURE: JS

RPM %	OIL TEMP °C OIL	PRESS. PSI
72	80	70

	ACCEPTED YES	ACCEPTED NO
3.1. ENGINE SHUTDOWN - COOL ENGINE AT GROUND IDLE FOR 3 MINUTES AND SHUTDOWN. NOTE: <u>PERFORM PROP BLEED - DOWN CHECK. (3.2.).</u>	JS	
3.2. PROP BLEED - DOWN CHECK - ON SHUTDOWN DO NOT SELECT REVERSE (LEAVE IN G.I. POSITION) TO ENGAGE THE PROPELLER START LOCKS. RECORD THE TIME IT TAKES THE PROPELLER TO ARRIVE AT FULL FEATHER. FROM SHUT DOWN: ≥ 15 Minutes ~~SECONDS~~	JS	

	SIGN OFF ACCEPTED YES	NO
3.3. LEAK CHECK THE ENGINE (FUEL-OIL-AIR) CORRECT AND LEAKAGE NOTED TO BE BEYOND LIMITS.	JB	
3.4. OIL FILTER CHECK - REMOVE AND REPLACE THE ENGINE OIL FILTER ELEMENT. INSPECT THE REMOVED FILTER FOR CONTAMINATION. INCLUDE THE REMOVED FILTER WITH AN OIL SAMPLE IN A SOAP KIT AND SEND IT TO ALLIEDSIGNAL FOR ANALYSIS.	JB	

4.0. <u>POST ENGINE REMOVAL CHECKS</u>

	YES	NO
4.1. REMOVE AND INSPECT THE CHIP DETECTOR FOR METALLIC CHIPS **. CLEAN AND REINSTALL	JB	

** NOTE: IF AN UNUSUAL AMOUNT OF METALLIC CONTAMINATION IS FOUND, NOTIFY ALLIEDSIGNAL, RENTAL ENGINE ADMINISTRATION, FOR ENGINE DISPOSITION.

	YES	NO
4.2. INSPECT ALL ENGINE PLUMBING LINES AND FITTINGS FOR SECURITY, CONDITION AND EVIDENCE OF FRETTING.	JB	
4.3 INSPECT ENGINE RIGGING FOR SECURITY AND/OR WORN ROD ENDS etc. CORRECT ANY DISCREPANCIES NOTED.	JB	
4.4. STATEMENT OF SERVICEABILITY THIS ENGINE HAS UNDERGOING ALL OF THE ABOVE CHECKS SUCCESSFULLY AND IS SUITABLE FOR RELEASE AND REUSE AS A RENTAL ENGINE. (EQUAL TO JAA FORM ONE / FAA 8031-3)	*** JB	***

*** NOTE: COMPANY - MGR., MAINT. - MGR. OR INSPECTOR MUST SIGN OFF ENGINE.

5.0. PREPARE ENGINE FOR SHIPMENT (if applicable)

	YES	NO
5.1. INSTALL SHIPPING COVERS AND CONFIGURE THE ENGINE IN ACCORDANCE WITH SERVICE INFORMATION LETTER No. 49 REV. 2. PACKAGE THE ENGINE IN A STANDARD ALLIEDSIGNAL SHIPPING CONTAINER (TPE331) FOR STORAGE OR SHIPMENT.	JB	

SIGN OFF	
ACCEPTED	
YES	NO
JS	

5.2. NOTE ANY UNUSUAL OR ABNORMAL CONDITION OF THE ENGINE THAT WAS OBSERVED DURING THE ABOVE CHECKS. FOR ASSISTANCE IN DETERMINING THE DISPOSITION OF THE ENGINE DUE TO ANY ABNORMAL CONDITIONS, CONTACT THE RENAL ENGINE ADMINISTRATOR AT ALLIEDSIGNAL.

NONE NOTED

THE ABOVE CHECKS ARE SIGNED OFF BY A CERTIFIED ENGINE MECHANIC OR INSPECTOR.

SIGNED: ____________________ 25/SEPT/2001

COMPANY MGR. OR MAINT. MGR. DATE

Appendix D

Log Book Page dtd April 22, 2010
(1 Page)

Ex. A, Page 81 of 104

ENGINE ☐
MODULE ☐
SERIAL NUMBER ____________

SERVICE RECORD

PAGE ______

DESCRIPTION OF INSPECTIONS, REPAIRS AND OVERHAULS
ENDORSE ALL INSPECTIONS AND REPAIRS WITH NAME, RATING AND CERTIFICATE NUMBER.

DATE	HOURS THIS FLIGHT	CYCLES THIS FLIGHT	ACCUMULATIVE TOTALS HOURS SINCE NEW	HOURS SINCE O/H	CYCLES SINCE NEW	CYCLES SINCE O/H	DESCRIPTION OF WORK PERFORMED
							TOTALS BROUGHT FORWARD

TPE331 SN P-42145C
10/21/03 TTE: 4393.1 TCE: 5165
Removed this Engine as a serviceable unit from the #1 position of N651VN on 21st October, 2003.
TT AF: 17884 TCAF: 22471 TTE: 4393.1 TCE: 5165.

Pertinent Details of
this repair are on
file under w.o. # 15430

signed ____ for
Lee Neal Aviation, Inc.
200 Pleasant Unity Rd. Suite 109
Latrobe, PA 15650
FAA Repair Station GY1R183K

This Logbook Closed April 22 2010

TOTALS TO DATE

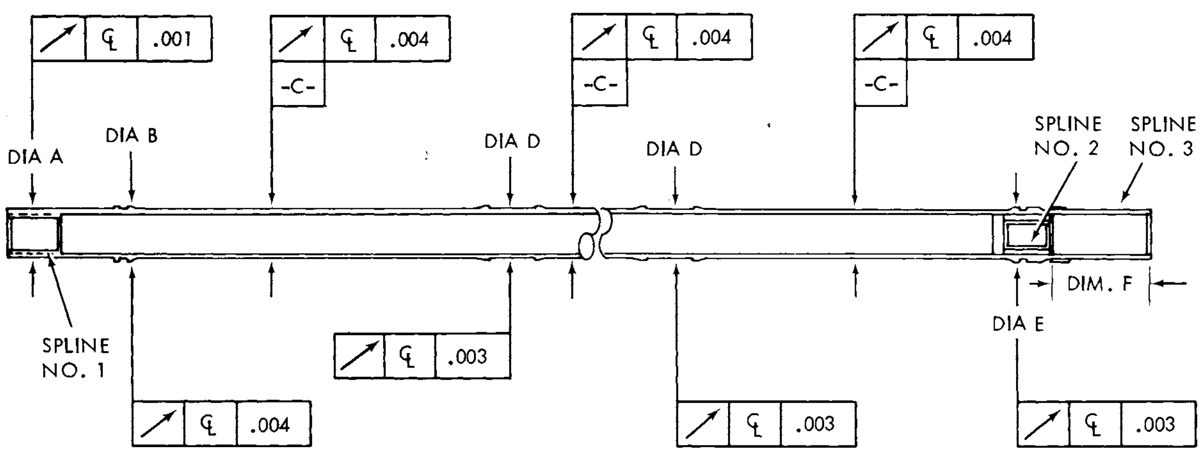
PX-3107-51

Appendix E

72-IR-15 Torsion Shaft Inspection
(3 Pages)

TORSION SHAFT ASSEMBLY PART NO. 3101758-1/-3 THROUGH -12

R NOTE: If Diameter D, Part No. 3101758-1/-3 through -6, is worn beyond
R limits specified, refer to Service Bulletin 72-0480. If Di-
R ameter D, Part No. 3101758-7/-8/-9, is worn beyond limits spe-
R cified, refer to Service Bulletin 72-0500.



Countersinks at both ends establish centerline.

SERVICEABLE LIMITS

DIA A	0.7439 to 0.7443 in.
DIA B	0.830 to 0.835 in.
DIA D	PN 3101758-1/-3 thru -6
R	0.742 to 0.746 in.
	PN 3101758-7/-8/-9
R	0.737 to 0.741 in.
	PN 3101758-10/-11/-12
R	0.732 to 0.736 in.
DIA E	0.859 to 0.861 in.
DIM. F	1.550 to 1.570 in.

Torsion Shaft Assembly
Figure 301

Figure 301 Inspection Procedures

R (1) Visually check splines of shaft for chipping, wear, and other damage.

(2) Perform spline wear inspection in accordance with Appendix 1, Inspection.

Spline Number 1, spline wear shall not exceed 0.005 inch.
Spline Number 2, spline wear shall not exceed 0.005 inch.
Spline Number 3, spline wear shall not exceed 0.005 inch.

(3) Inspect torsion shaft for straightness. See Figure 401 (Sheet 1), Repair (1).

(4) Perform magnetic particle inspection. Refer to Appendix 1, Method 203T. No cracks are allowed.

(5) Visually check condition of coupling. See Figure 401 (Sheet 2), Repair (3).

(6) Check torque load on Spline No. 2 by applying 218 inch-pounds torque. No slippage is allowed. See Figure 401 (Sheet 2), Repair (3), for coupling replacement.

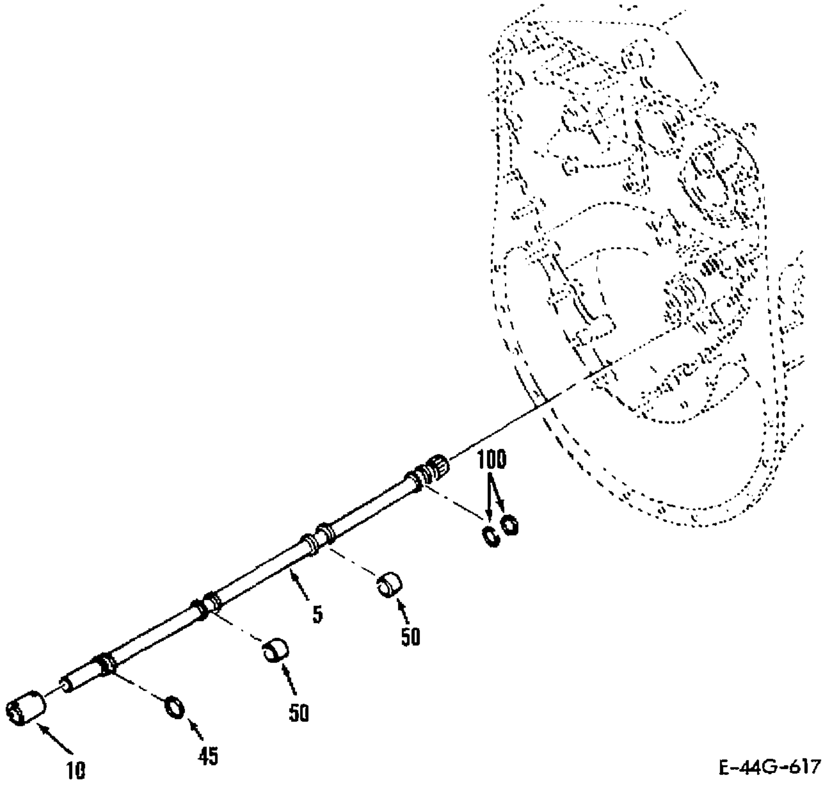
(7) Inspect Diameter A for wear. See Figure 401 (Sheet 1), Repair (2).

(8) Replace part that does not meet Inspection/Check requirements or is damaged beyond repair.

Appendix F

72-00-22 OHM Torsion Shaft Installation
(3 Pages)

Ex. A, Page 87 of 104



5. TORSION SHAFT (IPC, 72-10-14)
10. BUSHING
45. PACKING
50. BUSHING
100. RING

Installing Torsion Shaft Assembly
Figure 539

1. C. Torsion Shaft

(1) Install torsion shaft assembly as follows. *(See Figure 539.)*

(a) Assemble two rings (100) to torsion shaft (5) with slots 180 degrees apart.

(b) Determine proper size torsion shaft bushings (50) as follows.

1 Use largest dash number bushing as initial trial size.

2 Proper size bushing will have a slight resistance, but will not bind, when inserting torsion shaft (with bushing installed) into main shaft.

3 Bushing end gap must not be less than 0.005 inch when compressed on torsion shaft.

4 Using 285768-1-1 pliers, install trail size bushing (largest dash number) on torsion shaft aft journal.

5 Insert torsion shaft into main shaft from forward end. make sure criteria listed in Step 2 is met. If criteria is not met, repeat procedure using smaller dash number bushing. If torsion shaft, with bushing installed, can be inserted into main shaft and criteria listed in Step 2 is met, proper size bushing is determined. Remove bushing and set aside.

6 Repeat Step (b) for each torsion shaft journal to determine proper size torsion shaft bushings.

(c) Determine proper size torsion shaft bushing (10) as follows.

1 Use largest dash number bushing as initial trial size. Smaller dash number is smaller bushing.

2 Insert trial size bushing into forward end of main shaft. Proper size bushing will have a slight resistance but will not bind when inserted into main shaft. Use smaller dash number bushing until proper size bushing is determined. Remove bushing and set aside.

1\. C. (1) (d) Coat bushings (50) determined in Step (b) lightly with any approved engine oil. Using 285768-1-1 pliers, install bushings (20) on torsion shaft.

(e) Install packing (45) on torsion shaft (5).

Check Point 220:

1. Verify installation of seal rings on shaft with slots 180 degrees apart.
2. Verify bushings are installed on shaft.
3. Verify packing is installed.
4. Verify installation of shaft, with assembled parts, into main shaft.
5. Verify installation of bronze bushing on torsion shaft end. Maintain minimum slip fit between bushing and main shaft.

(f) Using 294208-1 torsion shaft puller, insert torsion shaft into main shaft from forward end. If required, compress bushings by hand to permit installation of torsion shaft assembly. Remove 294208-1 torsion shaft puller.

NOTE: Clearance between bushing (10) and main shaft must be 0.0002 to 0.0015 inch. Select proper size bushing to obtain clearance. Largest dash number is largest bushing.

(g) Install bushing (10) determined in Step (c), as torsion shaft is being installed.

Appendix G

EAM Torsion Shaft Acceptance and Installation Paperwork
(3 Pages)

Executive Aircraft Maintenance
E27R1730

Engine S/N P-42145

TPE331-GBIOH.G
Rev. Orig.

G/B O/H Inspection-ALL

W.O. 74017635

Nomenclature	Part No.	Serial No.	Qty.	Visual	Dim.	FPI	Mag.	Other	Accept	Reject	Repl. per SB	Notes
Oil Scav. Pump Assy.	865930-7	P128132	1	X						SS		conversion 3101321-20r-4
Oil Scav. Pump Hsg.	865931-3		1	X	X					SS		" 3101320-4
G-Rotor Set	865101-3		2	X	X				SS			
Shaft	865015-2		1	X	X		X		SS			
Oil Pres. Pump Assy.	867165-19		1	X						SS	SS	conversion 3103217-4 72-20
Housing			1	X								
Gear			1	X	X							
Rotor Set			1	X								
Shouldered Shaft S/Gbx Pump	897197-3	NA	1	X					SS			
Tube Assy.	865022-2	NA	1	X					SS			
Sun Gear Oil Jets	3104575-1/-2/-3		3	X	X	X			SS			~~conversion 3103432-1/-2/-3~~ SS
Sun Gear Brg. Oil Jet	867894-1		1	X	X	X			SS			~~conversion 3103431-1~~ SS
HSP Gear Oil Jet (Forward)	893730-1		1	X	X	X			SS			
HSP Gear Oil Jet (Aft)	893734-1	NA	1	X	X	X			SS			
Torsion shaft	3101758-6	98P04737	1	X	X		X		SS			1.557
Tach Gear Assy.	3107000-1	NA	1	X								
Gear 1	896808-5		1	X					SS			
Gear 2	896906-1		1	X					SS			
Nut 1	896853-1		1	X					SS			
Nut 2	896814-1		1	X					SS			
Spacer	896830-1		1	X					SS			
Bearing	358272		1	X						SS		100% OH
Bearing	358348		1	X						SS		" "
Bearing	358894-1		1	X						SS		100% Replacement Upon Removal
Torque Sensor	3101726-2	P-7561	1	X						SS	SS	72-0555 3101726-3
Accessory Gear Hsg. Assy.	NA		1	X								Strain Gage Engines Only
Compressor Brg. Nut	893726-1	NA	1	X			X		SS			
Spur Gear	866306-6	NA	1	X			X		SS			
Compressor Brg. Retainer	894533-4		1	X					SS			
Compressor Brg. Carrier	868897-10	NA	1	X					SS			
Compressor Seal Assy.	3107051-1		1	X						SS	SS	100% OH 3107051-5 72-20
Compressor Brg.	3101405-1	96-14414-15822	1	X						SS	SS	" " 3103708-1

NDT Inspection Report

Engine S/N P-42145C

W.O. 74017635

Engine Model No. TPE331-10UF-513H Engine Manual No. 72-00-43 72-IR-15 Pg. 1 of 2
Engine Part No. 3102600-6 Engine Manual Rev. No. 9

Nomenclature	Part No.	Serial No. / Lot No.	Qty.	FPI	MPI	Accept	Reject	Reason for Rejection	Insp Stamp or Signature
2nd impeller	893482-3	4-03501-2722	1	X		1	Ø	None	
Mainshaft	3101672-2	3P-31070	1	X	[illegible]		Ø	None	
Plenum	3101668-11		1	X		1	Ø	None	
Ring gear	893757-1		1		X	1	Ø	None	
Coupler	894119-1		1		X	1	Ø	None	
Torsion Shaft	3101058-6	95P04737	1		X	1	Ø	None	
Quill	894124-1		1		X	1	Ø	None	
Oil Jet	896944-1		1	X		1	Ø	None	
Nut	866731-1		1	X		1	Ø	None	
Propshaft	896126-4	4-18040-943	1		X	1	Ø	None	
Oil Jet	893730-1		1	X		1	Ø	None	
Oil Jet	893734-1		1	X		1	Ø	None	
Starter gear	3103192-2	5P-27018	1		X	1	Ø	None	
Idler gear	3103119-1		1		X	1	Ø	None	
Hydraulic gear	895900-2		1		X	1	Ø	None	
Gov gear	867883-1		1		X	1	Ø	None	
Nut	893726-1		1		X	1	Ø	None	
Gear	866306-6		1		X	1	Ø	None	
Labyrinth Seal	894084-2		1		X	1	Ø	None	
Vane plate	893384-3		1	X		1	Ø	None	
OTL	3102102-3		1	X		1	Ø	None	
Rear Support	3101529-5	5P-31141	1	X		1	Ø	None	

Ref. 72-10-14

Engines Having Hydraulic Torque Sensors. Check Turbine Pump Drive Coupling in Torsion Shaft for:

1. Proper Positioning. Limits, 1.550 to 1.570

   Actual Measurement = 1.557 .

2. Check Coupling for Security by Applying 218 . Inch Pounds Torque. No Movement Allowed.

3. Install Torsion Shaft Assembly.

Mechanic KS . Inspector GG .

Ref. 72-10-16

Torque Sensor Installation.

Calculate Shims used to Position Torque Sensor Body 6.290 to 6.300 inch, Measured From Face of Gearbox.

Face of Gearbox to Compressor Bearing Carrier Retainer

Maintenance Manual Dim. 6.290 to 6.300 ADJUSTED SHIMS .

Required Shims +/- 0.005 = .082 . 6.295

Mechanic KS . Inspector GG .

Appendix H

Texas Turbine Flight Test Log
(4 Pages)

10

ENGINEERING TEST CARD – Stall Characteristics AFT CG

ETP: 100 FTP: 3

Model DHC-3 Down [illegible] Date 10/4/00 Flight No. 9

Serial 115 Up 2.25 FAA E [illegible] Company T. Bishop

N- 12rBA Total [illegible]

Loading A/H Weight 8292 CG at 152.54 Start Fuel Lt FULL Rt

EOT Fuel Lt Rt

Configuration 50/100/60

Test used 56 gallons

Page 1 of 4

Cond	Test Description	Test Data & Results
	Climb to a safe altitude of at least 5000 AGL and verify test area is free of other aircraft.	
1	**Wings Level Stalls (power idle, flaps retracted):** Reduce power to flight idle and trim to 1.5 V_{s1} = 116 mph. At approximately ~~84~~ 83 mph, attain a 1-mph / second deceleration rate till stall occurs, or elevator control reaches stop. Recover initially without adding power until $1.2V_{S1}$ (92 mph) is reached. Record speed where stall warning is observed. Record speed where stall occurs, or elevator control reaches stop. Record altitude loss, and aircraft pitch (below level), roll, and yaw angles, and maximum airspeed reached during recovery. Also, record fuel consumed so aircraft weight can be determined/verified.	Stall Warning 84(L) Stall/elev. Stop stop 75 Alt. Loss [illegible] 150 Pitch Down 10 Roll Angle ±5 Yaw Angle ±5 Max Airspeed Recovery 95 Fuel Used 12.8 / [illegible]
4 2	**Wings Level Stalls (power on, flaps retracted):** Set power to 75% torque and trim to 1.5 V_{s1} = 116 mph. At approximately ~~84~~ [illegible] mph, attain a 1-mph / second deceleration rate till stall occurs, or elevator control reaches stop. Recover using flight controls and power as required. Record speed where stall warning is observed. Record speed where stall occurs, or elevator	Stall Warning 77 Stall/elev. Stop 70 Alt. Loss 50 Pitch Down 0 Roll Angle ±10 Yaw Angle ±5

Config. trim

	control reaches stop. Record altitude loss, and aircraft pitch (below level), roll, and yaw angles, and maximum airspeed reached during recovery. Also, record fuel consumed so aircraft weight can be determined/verified.	Max Airspeed Recovery 85 Fuel Used 22.2 / 8143 20-25# just prior to stop slight left wing drop
3	**Wings Level Stalls (power idle, flaps ~~TAKEOFF~~):** Reduce power to flight idle and trim to 1.5 V_{s1} = 86 mph. At approximately 69 mph, attain a 1-mph / second deceleration rate till stall occurs, or elevator control reaches stop. Recover using only flight controls initially. Once reaching approximately $1.2V_{S1}$ (68mph), power may be used to aid recovery. Record speed where stall warning is observed. Record speed where stall occurs, or elevator control reaches stop. Record altitude loss, and aircraft pitch (below level), roll, and yaw angles, and maximum airspeed reached during recovery. Also, record fuel consumed so aircraft weight can be determined/verified.	Stall Warning 61 (L) Stall/elev. Stop 55 10-12 lbs Alt. Loss 150 Pitch Down 8 Roll Angle ± 5 Yaw Angle ± 5 Max Airspeed Recovery 80 Fuel Used 15.3 / 8179
~~4~~ 5 4	**Wings Level Stalls (power on, flaps ~~TAKEOFF~~):** climb Set power to 75% torque and trim to 1.5 V_{s1} = 86 mph. At approximately 69 mph, attain a 1-mph / second deceleration rate till stall occurs, or elevator control reaches stop. Recover using flight controls and power as required. Record speed where stall warning is observed. Record speed where stall occurs, or elevator control reaches stop. Record altitude loss, and aircraft pitch (below level), roll, and yaw angles, and maximum airspeed reached during recovery. Also, record fuel consumed so aircraft weight can be determined/verified.	Stall Warning 55 Stall/elev. Stop 45-43 Alt. Loss 100 Pitch Down -5 Roll Angle 10° Left Yaw Angle 5° Left Max Airspeed Recovery 80 Fuel Used 25.8 / 8111 15-17#. Left rud on stop b/stall. Elev. softened. Rud force 60# at brk Force on rud incr. norm.
4 3 5	**Wings Level Stalls (power idle, flaps LANDING):** Reduce power to flight idle and trim to 1.5 V_{s1} = 78 mph. At approximately 65 mph, attain a 1-mph / second deceleration rate till stall occurs, or elevator control reaches stop.	Stall Warning 57 (L) Stall/elev. Stop 55 10 lbs, -15 pulsing Alt. Loss 250' Elev. lightened Pitch Down 20°

	Recover using only flight controls initially. Once reaching approximately 1.2V$_{S1}$ (62 mph), power may be used to aid recovery. Record speed where stall warning is observed. Record speed where stall occurs, or elevator control reaches stop. Record altitude loss, and aircraft pitch (below level), roll, and yaw angles, and maximum airspeed reached during recovery. Also, record fuel consumed so aircraft weight can be determined/verified.	Roll Angle ± 2° Yaw Angle ± 2 Max Airspeed Recovery 75 Fuel Used 17.6 / 8[illegible]
#6 6	**Wings Level Stalls (power on, flaps LANDING):** Set power to 75% torque and trim to 1.5 V$_{s1}$ = 78 mph. At approximately 65 mph, attain a 1-mph / second deceleration rate till stall occurs, or elevator control reaches stop. Recover using flight controls and power as required. Record speed where stall warning is observed. Record speed where stall occurs, or elevator control reaches stop. Record altitude loss, and aircraft pitch (below level), roll, and yaw angles, and maximum airspeed reached during recovery. Also, record fuel consumed so aircraft weight can be determined/verified.	Stall Warning 50(L) Stall/elev. Stop 43 Alt. Loss 150 Pitch Down 10° Roll Angle 30° R Yaw Angle 10° L Max Airspeed Recovery 80 Fuel Used 30.3 / [illegible] Same as Rud on stop prior to pitch breaker Inital roll of 10°-12° right that progressed up to 30° with buffet
# 7	**Turning Stalls: LEFT TURN** Set power to 75% torque and trim to V$_Y$ (93 mph). Establish and maintain a steady coordinated 30° bank left turn. Progressively tighten the turn with the elevator control until the airplane is stalled or until the elevator has reached its stop. Recover to level flight. Note if other than normal use of controls is necessary during recovery. Record altitude loss, and aircraft pitch (below level), roll, and yaw angles, and maximum airspeed reached during recovery. Also, record fuel consumed so aircraft weight can be determined/verified.	Stall Warning 80(L) Stall/elev. Stop 72 on stop w/buffet Alt. Loss -50 Pitch Down 10 Roll Angle +10 Yaw Angle +5 Max Airspeed Recovery 80 Fuel Used 36.2 / 80[illegible] Controls Normal YES NO
# 8	**Turning Stalls: RIGHT TURN** Set power to 75% torque and trim to V$_Y$ (93 mph) Establish and maintain a steady coordinated 30° bank right turn. Progressively tighten the turn with the elevator control until	Stall Warning 83 Stall/elev. Stop 70 Elev. softened slightly

A/C wanted to roll left

	the airplane is stalled or until the elevator has reached its stop. Recover to level flight. Note if other than normal use of controls is necessary during recovery. Record altitude loss, and aircraft pitch (below level), roll, and yaw angles, and maximum airspeed reached during recovery. Also, record fuel consumed so aircraft weight can be determined/verified.	Alt. Loss -50 Pitch Down 2 Roll Angle -5 (to left) Yaw Angle 0 Max Airspeed Recovery 80 Fuel Used 39.0 [illegible] Controls Normal YES NO
	End of Test	

Elev.

RESULTS

___ Satisfactory X Satisfactory w/ conditions ___ Unsatisfactory

[signature] FAA ______________________ Company

Notes:

TEST CONDITION 4 + 6 END POINT DEFINED BY RUDDER PEDAL TRAVEL LIMIT VICE PITCH BREAK. DESCRIPTION OF THIS CHARACTER WILL BE PROVIDED IN AFMS

Attachment 1

(1 Page)

Listing of Depositions and Trial Appearances

Listing of Depositions and Trial Appearances

Of

David Studtmann

As of Sept 27, 2017

Plaintiff V. Defendants	Type	Date
ROBERTSON, et al. v. HONEYWELL INTERNATIONAL, INC., et al	Deposition	May 27-28, 2015
JEFFREY BOATMAN and ANNE BOATMAN v. UNIFLIGHT, LLC	Deposition	March 15, 2016

Attachment 2

(2 Pages)

Curriculum Vitae

DAVID E. STUDTMANN

Honeywell Aerospace
1944 E Sky Harbor Circle N, Mail Stop 2102-121, Phoenix, AZ 85034
Office: (602) 365-2414 • Cellular: (602) 203-3205 • Email: david.studtmann@honeywell.com

SUMMARY OF SKILLS:

- Able to complete tasks with potentially limited information while making effective risk decisions
- Capable of leading and working well with many different business professionals
- Efficient in instructor and mentoring roles with excellent personnel relations
- Excellent written and verbal communications skills

AREAS OF KNOWLEDGE:

• Failure Analyses
•Turbine Engine Systems
•Rotary & Fixed Wing Systems
•Accident Reconstruction
•Product and System Safety
•Airframe Electronic Systems
•Product Liability Litigation Support
•Worldwide Accident Investigation
•Six Sigma Tools & Processes

PRESENT WORK EXPERIENCE:

Honeywell International Inc, AlliedSignal Corp, Phoenix, Arizona • 1997 to Present

Staff Engineer, Product Safety Specialist, Air Safety Investigator – Product Integrity

- 12+ years of corrective action program experience including both electronic and mechanical based CSB assignments, accident/incident investigation experience and product liability litigation support.
- Participated in approximately 200 investigations in support of Honeywell's product portfolio
- Product Integrity representative for monthly MCOE and MSEA Safety of Flight meetings and frequent Chairperson of Product Integrity Committee meetings
- Possesses practical experience in understanding and interpreting various risk analysis methodologies
- Participates in all phases of accident/incident investigations worldwide, from on-scene thru corrective action implementation on a variety of platforms including; business/corporate fixed wing aircraft, transport category aircraft, agricultural/restricted category. rotorcraft, and UAVs
- Championed multifunctional team to develop ITAR/EAR PMOS for Product Integrity personnel and developed submission to US Department of State for ITAR Exemption for the purpose of aircraft accident investigation
- Developed problem statement and teamed with Honeywell Chiefs Organization to standardize the significant variation in engine preservation methodologies across Honeywell products
- Mentored and trained numerous individuals both within and outside the Product Integrity Organization in accident investigation procedures and corrective action programs
- Product Integrity focal point for the Honeywell TFE731-50BR turbofan engine Part 33 and IPPS Part 25 certification for the Hawker 900XP platform
- Successfully utilized FAA Suspected Unapproved Parts process and findings to thwart litigation against Honeywell to obtain ruling for dismissal with prejudice

Six Sigma Black Belt II, Product Support and Delivery – Integrated Supply Chain, Circular and Rotating

- Represented the Six Sigma Plus organization in the day to day and strategic operation of the Circular and Rotating Center of Excellence
- Led and mentored cross functional teams in the use of six sigma tools and concepts
- Assumed cell production leader responsibilities when required and executed to meet customer requirements
- Competed and implemented hand finish reduction (Black Belt) project to reduce cost of poor quality, lead time, and potential health risks
- Focal point for the Integrated Supply Chain activities of 5S and Standard Work In Process within the Circular and Rotating Center of Excellence
- Developed plan and functionality requirements for the e-shop labor tracking system that eliminated an antiquated hardware tracking system and database to provide greater visibility of hardware flow through the CoE

Manufacturing Engineer II, Assembly & Test Engineering

- Production Support Team leader responsible for resolving technical issues for the Assembly & Test of the TFE731/CFE 738 product lines
- Worked closely with management and quality functions to ensure consistent product is delivered to the customer, addressed process changes when required, and followed up with vendors for cause and corrective actions
- Monitored key engine attributes in attempt to eliminate costly and recurring discrepancies
- Represented manufacturing and operations input at CSB meetings
- Participated on diverse team that implemented dress standards manuals and reduced the customer squawk rate by more than 75% over the period of one year
- Resolved five year assembly line problem with spinner support D-nuts by utilizing Six Sigma tools and processes and eliminated the hidden factory work associated with the cost of poor quality

Propulsion Test Technician/Engineer/Team Leader

- Supervised test procedures of TFE731, CFE738, ATF3, ALF502/507 and T55/T53
- Acted as focal point for transition of AS907/977 from development to production test
- Utilized time saving measures to reduce engine turn time and increase productivity by implementing process improvements based on the 5S principles. I.e. Monopole test fixture, redesign of ATF3 interface harness.
- Coordinated engine activity and manpower to produce optimum yield
- Built and reinforced strong relationship with Honeywell's Repair and Overhaul leadership

PAST WORK EXPERIENCE

Evergreen Air Center Incorporated, Marana, Arizona

Contract Airframe and Powerplant Mechanic

- Developed trusted relationship with NASA customer representative on DC8 "D" check and acted as focal point for program updates
- Conducted repairs on routine and non-routine discrepancies based on work scope
- Researched appropriate ATA codes to comply with proper repair procedures and inspection operations
- Installed components and systems on heavy turbine aircraft
- Familiarized with various airframes and related integrated systems

EDUCATION:

Bachelor of Science, Purdue University, West Lafayette, Indiana
Degree in Aeronautical Technology, 1995

Master of Science, Embry-Riddle University, Extended Campus, Mesa, Arizona
Degree in Technical Management with Honors Distinction, 2005

RATINGS, LICENSES AND CERTIFICATES:

- Instrument Pilot, Single Engine Land
- Remote Pilot Airman Certificate with a Small UAS Rating
- Airframe & Powerplant Mechanic License
- Eddy Current, NDT Level I Qualified
- Magnetic Particle, NDT Level I Qualified
- Liquid Penetrant, NDT Level I Qualified
- Black Belt Certification, Honeywell Six Sigma Plus
- Certificate in Aviation Safety and Security, University of Southern California, 2009

ASSOCIATIONS:

- International Society of Air Safety Investigators, Member #AO5146
- General Aviation Air Safety Investigator Society